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Introduced and moderated by Alain Gilbert and Howard Clarke

Scientific paper session 2: OBPL general
Introduced and moderated by Lynda Yang and Jörg Bahm

Scientific paper session 3: Brachial plexus adults/nerve general
Introduced and moderated by Michael Fox and Tim Hems

Scientific paper session 4: Brachial plexus adults/nerve general
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Scientific paper session 5: Shoulder OBPL
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Scientific paper session 6: Shoulder OBPL & Adult
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1.1 The natural history of recovery of elbow flexion after obstetric brachial plexus injury managed without nerve repair

T.E.J. Hems, T. Savaridas, D.A. Sherlock
Queen Elizabeth University Hospital, Glasgow, United Kingdom

We report the outcome for spontaneous recovery of elbow flexion in obstetric brachial plexus injury (OBPI) managed without nerve reconstruction.

Before 2008 our unit did not routinely offer nerve exploration and reconstruction. Children born before 2008 were identified from our database. 232 children had been assessed for OBPI. 80 had full early recovery, leaving 152 with a persisting deficit. These cases are followed up until skeletal maturity. The Narakas group was known for 149 children; 58 group 1, 55 group 2, 24 group 3, and 12 group 4. Five children had nerve repair. Of 147 managed without nerve exploration, only one patient had been noted to have insufficient elbow flexion to reach their mouth. Elbow flexion started to recover clinically at a mean age of 4 months for Narakas group 1, 6 months for group 2, 8 months for group 3 and 12 months for group 4. The mean active range of elbow flexion, measured in 44 cases, was 138 (Range 110–160). The mean isometric elbow flexion strength, measured in 39 patients at a mean age of 12.6 years (Range 5 to 22), was 8.7KgF, 63% (Range 23 - 100%) of the normal side, 68% for group 1 injuries, 61% group 2, 64% group 3, and 62% group 4.

It appears to be rare for elbow flexion not to recover spontaneously, although recovery occurs later in more severe injuries. It is doubtful if nerve reconstruction can improve elbow flexion beyond the likely spontaneous recovery in children with OBPI.
1.2 Exploring the Incidence of Isolated Dorsal and/or Ventral Rootlet Disruption (Avulsion) by High-Resolution MRI in Neonatal Brachial Plexus Palsy (NBPP)

L.J.S. Yang, B.W. Smith, K.W. C. Chang, H. Parmar
University of Michigan, Ann Arbor, United States of America

Introduction: Avulsion injury of a nerve root in NBPP generally precludes its use as a donor for nerve reconstruction. Traditional imaging, e.g. myelograms, early CT-myelograms, provided indirect evidence via the presence of pseudomeningoceles as an indicator of an avulsed nerve root. The introduction of high resolution MRI allowed direct visualization of individual rootlets and their integrity. The purpose of our study was to determine the incidence of isolated ventral and/or dorsal nerve rootlet avulsion via high resolution MRI.

Methods: We conducted a retrospective review of MRI imaging of NBPP infants from 2010-2018. A single board-certified neuro-radiologist who was blinded to the clinical presentation and later outcomes reviewed each dorsal and ventral nerve rootlet at the C5-T1 levels from the spinal cord to its exit in the neuroforamina. Descriptive statistics were used to describe the ventral intact and ventral not-intact rootlets.

Results: Sixty infants (600 nerve roots; mean age 5±2mos) were included. Only 2/600 (0.33%) nerve roots were unreadable. Surprisingly, of the total avulsed nerve roots, C7 was most commonly disrupted (31%). Overall for each “avulsed” nerve root, 31% to 40% of the ventral rootlets were deemed intact.

Conclusion: High-resolution MRI allows 99+% readability in the determination of nerve rootlet integrity. Given the increasing incidence of pan-plexopathies, conservation of potential nerve root donors for nerve reconstruction is critical. We suggest that MRI can be of assistance in the pre-operative planning of the surgical strategy by identifying certain “avulsed” nerve roots as potentially viable donors.
1.3 Exploring Tissue Viability Imaging (TiVi), Skin Temperature and Stimulated Skin Wrinkling Asymmetry as potential tools for the evaluation of Obstetric Brachial Plexus Injury (OBPI)

C. DeMatteo, T.P. Packham, J.R. Bain, D. Gjertsen, D. Schutten, M. Huxtable, A. Ahmad, N. Jacob
McMaster University, Hamilton, Canada

Measurement of skin temperature asymmetries, stimulated skin wrinkling (SSW), otherwise known as, the ‘wrinkle test’ and visualizing microcirculation in the upper dermis using Tissue Viability Imaging (TiVi) may allow for improved early evaluation of severity of nerve injury in OBPI. TiVi, uses a digital camera equipped with polarization filters and user-friendly software for presenting the skin microvascular blood concentration in two-dimensional digital video images. Measurement of skin temperature asymmetry with a handheld infrared thermometer and SSW using EMLA cream, both provide simple, painless and cost-effective methods that could be used in conjunction with other diagnostic methods to improve decision making re the need for surgery after OBPI.

The results of a pilot cross sectional study on infants and young children with OBPI in which all three methods were administered and showed significant differences between the affected and unaffected limbs will be presented. These results will be correlated with other measures of impairment: Active Movement Scale; Narakas Classification Level, and other diagnostic tests when available. Infants and children who have had primary reconstructive nerve surgery and those who have not, will both be included in the final sample. These new methods provide innovative, efficient and perhaps easily standardized techniques of evaluation of the extent of nerve injury.
1.4 Outcome of Microsurgery for BPBI Before Versus After 6 Months of Age: Results of the Multicenter TOBI Study

A.S. Bauer¹, L.A. Kalisch¹, M.J. Adamczyk², D.S. Bae¹, R. Cornwall³, M.A. James⁴, N. Lightdale-Miric⁵, A.E. Peljovich⁶, P.M. Waters¹

¹Boston Children’s Hospital, Boston, United States of America
²Akron Children’s Hospital, Akron, United States of America
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⁶Children’s Healthcare of Atlanta, Atlanta, United States of America

Background: The timing of nerve surgery in infants with brachial plexus birth injury (BPBI) is controversial. The Treatment and Outcomes of Brachial plexus Injuries (TOBI) study is a multi-center prospective study designed to determine the optimal timing of this surgical intervention. This study compared outcomes evaluated 18-36 months after “early” (age 6 months) versus “late” (age 6 months) microsurgery.

Methods: 118 subjects were included based on having a nerve graft and/or transfer and at least one physical examination during the interval 18 to 36 months after microsurgery but before any secondary surgery. Surgical timing was dichotomized as before or after 6 months of life. Postoperative outcomes were measured using the total Active Movement Scale (AMS) score as well as the change in AMS score. To address hand reinnervation, a hand function subscore of the AMS was used to repeat the analysis among patients with global injuries.

Results: Eighty subjects (67%) had early surgery (at a mean 4.2 months); 38 (32%) had late surgery (at a mean 10.7 months). Infants who underwent early surgery tended to enroll earlier and have more severe injuries. When controlled for severity, the difference in AMS scores between early and late surgery groups was not significant. In patients with global injuries, there was no difference in the postoperative AMS hand subscore in the early versus late groups.

Conclusions: This study suggests that earlier surgery does not lead to better outcomes in BPBI nerve surgery, including reinnervation of the hand in global injuries.
1.5 Treatment Variation in Brachial Plexus Birth Injury Across Academic Medical Centers in North America

A.S. Bauer, C.B. Vuillermin, A. Kunnimal, R. Cornwall, A. Tartarilla, P.M. Waters

1Boston Children’s Hospital, Boston, United States of America
2Cincinnati Children’s Hospital Medical Center, Cincinnati, United States of America

Purpose: There are limited consensus-based guidelines for surgical treatment of Brachial Plexus Birth Injury (BPBI). This study investigated the variation in surgical care for BPBI among centers in the United States.

Methods: Treatment and Outcomes of Brachial plexus Injuries (TOBI) is a multi-center prospective study of BPBI patients. We analyzed 781 TOBI subjects at 6 sites (site A: 43%, B: 19%, C: 13%, D: 13%, E: 10%, and F: 2%). Binary logistic regressions and chi-squared tests were used to assess variation in microsurgery and secondary shoulder procedures (SSP) (botulinum toxin injection, contracture release, and/or tendon transfers). Site A had highest enrollment and was used as the baseline for comparisons.

Results: Subjects were enrolled at a median of 3 months of age. There was significant site variation in enrollment age (0.001). 218 subjects (28%) underwent microsurgery, at a median of 6 months of age. There was site variation in the likelihood of undergoing microsurgery, with an increased odds ratio (OR) of microsurgery at sites B (OR=5.1) and site C (OR=6.2) versus site A. Of the 218 subjects who underwent microsurgery, 55% underwent SSP. Of the 563 subjects who did not undergo microsurgery, 23% underwent SSP. While there was no difference in the rate of SSP across sites, there was significant variation in the type of SSP (0.001). (Table 1).

Conclusion: Variation exists in the surgical care of BPBI among centers in the TOBI study. This variation includes the likelihood of receiving microsurgery as well as the types of SSP performed.
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2.1 Tension on peripheral nerve suture

J. Bahm
Franziskushospital, Aachen, Germany

It is shared common knowledge that a peripheral nerve suture should be done without undue tension. After a literature review and confrontation with clinical situations where the nerve gap could be reduced and tension neutralized by specific suture material, we designed a surgical strategy to repair selected upper and extended upper obstetric brachial plexus lesions by neuroma excision at the trunk level and direct suture-coaptation. As the clinical outcome in a retrospective cohort was rather good after more than 2 years of follow up, we continued to work on this paradigm and biological conditions for nerve regeneration and present our state of knowledge for discussion.
2.2 Exploration of Fascicular Shift Procedure in OBPL

O. Aszmann, M. Sporer
Medical University of Vienna, Vienna, Austria

Introduction: Modality matched grafting has proven to provide best results in nerve regeneration. These grafts are obviously difficult to obtain in an autologous setting and thus expandable sensory nerve grafts remain the gold standard to overcome nerve defects. Recently we have investigated the use of sensory-motor fascicles distal to the defect to bridge the gap. Here we present the use of fascicular shifts and long term outcome in a cohort of 4 children that suffered global plexopathies.

Material and Methods: In four children with severe Narakas IV lesions, autologous nerve grafts have been harvested from various trunc nerves distal to the lesion to overcome the devastating defect of all five roots. Intraoperative documentation of cases and cadaveric specimen are presented to depict the various options to harvest expandable fascicles. Finally, more than three year follow-ups are provided with video material and the classic scores for shoulder, elbow and hand function.

Results: This material proves the feasibility of modality matched grafting using fascicular shifting both from cadaveric material and a first cohort of 4 OBPL patients. The data provided indicates that even in the face of a global plexopathy the entire defect can be grafted and a good outcome can be achieved.

Conclusion: The cadaveric data indicates the various regions of the brachial plexus where sufficient length of fascicular material can be harvested. Longterm follow-up data proves that using fascicles distal to the injury can help to overcome the bottleneck in nerve regeneration and a good outcome can be achieved.
Shoulder outcomes following primary nerve reconstruction of neonatal brachial plexus palsy: Analysis of predictors and surgical strategies

R. Tse, S. Lewis, M. Osorio
Seattle Children’s Hospital, Seattle, United States of America

Methods to re-animate elbow flexion can be reliable whereas reconstruction of shoulder function remains inconsistent and suboptimal. The purpose of this study was to assess shoulder motor recovery following primary nerve reconstruction in order to identify factors that may affect outcome.

Methods: Retrospective review of all infants undergoing nerve reconstruction for NBPP was conducted. Indications for surgery followed the Toronto protocol. Pre-operative and 2-year post-op active movement (abduction, flexion, and external rotation) was assessed. Changes and differences were assessed by ANOVA and subgroup analysis involved Wilcoxon test.

Results: Over an 8-year period 450 patients presented to our center. Forty-eight patients underwent nerve reconstruction. Two patients were excluded given that they underwent isolated distal nerve transfers for elbow flexion alone. Overall, there were significant improvements in abduction, flexion, and external rotation (0.05). Palsy type, number of avulsions, and head injury were associated worse outcome. In order to control for timing and initial severity, subjects were grouped by surgical indication. We found no difference when nerve grafts were combined with nerve transfers or when nerve transfers alone were used. There was an association of number of cable grafts and abduction and external rotation (0.05).

Conclusions: Shoulder function improved significantly following primary nerve reconstruction. The greatest changes were in subjects with more severe palsies. Nerve transfers as adjuncts to nerve grafting may have facilitate these larger changes, however, the role of additional adjunctive transfer in improving outcomes requires larger study of subjects isolated by specific surgical indications.
2.4 Double nerve transfer for shoulder external rotation restoration in OBP

F. Soldado,
Barcelona, Spain

Aim:
To analyze the outcomes following Double nerve transfer for shoulder external rotation restoration in OBP

Methods:

Indication:
OBP with absence of active shoulder external rotation at 18 months of age.

Technique:
SAN to nerve to the infraspinatus by a dorsal approach. Nerve to the long head of triceps to the nerve to the teres minor by a axillary approach. Active shoulder external rotation in ABD is evaluated.

Results:
Fourteen patients were operated. Mean age 19.3 months, mean follow-up 13 months.
Mean aERABD 62 (45-80)

Conclusions:
Double nerve transfer for shoulder external rotation restoration in OBP
2.5 Mid-term Outcome after Selective Neurotization of the Infraspinatus Muscle in Patients with Brachial Plexus Birth Injury

P.G Grahn, A.S. Sommarhem, Y.N. Nietosvaara
New Children’s Hospital, Helsinki, Finland

Hypothesis: Active shoulder external rotation (ER) in adduction and abduction can be restored by selective neurotization of the infraspinatus nerve using the spinal accessory nerve in patients with brachial plexus birth injury (BPBI).

Methods: 14 consecutive BPBI patients with active external rotation in adduction of less than 10° and active shoulder elevation above 90° underwent neurotization of the infraspinatus nerve at median age of 2 years (1.4-4.7) between 2012 and 2016. Pre-operatively all patients had congruent shoulders with passive ER in adduction of 45°. Winging of the scapula was evident in 8/14 patients. Clinical follow-up was scheduled at 3, 6, 12, 24 and 36 months after surgery. Pre- and postoperative EMG was done to 7 patients. Parents’ satisfaction of the functional and cosmetic result was obtained at median follow-up time of 3.2 years (1.6-5.4).

Results: The median improvement of ER in adduction was 58° (range 30°-70°) in 12/14 patients. Two children developed internal rotation contracture of their shoulders with no improvement in active ER. Shoulder abduction improved in all but one patient (median 48° range 25°-80°). All seven patients with EMGs showed recovery of infraspinatus function. Pre- (8) and postoperative registered (3) winging of the scapula decreased during follow-up. Hypertrophic scars were observed in seven patients. All but one patient’s parents were satisfied.

Summary points: Functionally significant active external rotation can be restored and maintained by direct neurotization of the infraspinatus muscle in BPBI patients with congruent shoulder joints and no internal rotation contracture.
2.6 Sensibility of the Hand in Children With Conservatively or Surgically Treated Upper Neonatal Brachial PlexusLesion

W. Pondaag, S.M. Buitenhuis, M.J.A. Malessy
Leiden University Medical Center, Leiden, Netherlands

BACKGROUND The aim of this study was to assess the sensibility of the hand in children with a neonatal brachial plexus palsy (NBPP) involving the C5 and C6, and to correlate results with dexterity.

METHODS Fifty children with NBPP (30 after nerve surgery, mean age 9.8 years) and 25 healthy controls (mean age 9.6 years) were investigated. Sensibility was assessed with two-point discrimination and Semmes-Weinstein monofilaments. Dexterity was evaluated with a single item from the Movement Assessment Battery for Children-2. We compared the affected side with the nondominant hand of the control group.

RESULTS The sensibility in the first and second fingers was significantly diminished in the NBPP for both two-point discrimination (P=0.005 and P=0.014, respectively) and monofilament test (P 0.001). Dexterity was significantly lower in the NBPP group than in control group, corrected for age (P=0.023). There was a significant difference toward decreasing hand function with decreasing sensibility according to the Semmes-Weinstein test for the thumb (Jonckheere-Terpstra nonparametric trend test, P=0.036).

CONCLUSIONS The sensibility of the thumb and index finger in children with an upper plexus lesion (either surgically or conservatively treated) is diminished. The decreased sensibility has a negative impact on hand function. Appreciation of diminished hand function in patients with NBPP involving CS and C6 is important to optimize treatment.
2.7 The Hand-Use-at-Home Questionnaire to assess spontaneous hand-use in children with unilateral paresis: evidence for validity and reliability

M. van der Holst¹, Y. Geerdink², P. Aarts², R. Lindeboom³, J. van der Burg³, B. Steenbergen⁴, D. Steenbeek¹, W. Pondaag¹, R.G.H.H. Nelissen¹, T.P.M. Vliet Vlieland¹, A.C.H. Geurts⁴
¹Leiden University Medical Center, Leiden, Netherlands
²Sint Maartens kliniek, Nijmegen, Netherlands
³Amsterdam University Medical Centre, Netherlands
⁴Radboud University, Netherlands

Introduction: We developed the parent-rated Hand-Use-at-Home questionnaire (HUH) to assess the amount of spontaneous use of the affected arm/hand in daily-life activities in children with unilateral paresis, aged 3-10 years. This study describes its development and examination of the internal structure, unidimensionality, validity and test-retest reliability.

Patients and methods: Children with Unilateral Cerebral Palsy (UCP) or Neonatal Brachial Plexus Palsy (NBPP) and Typically Developing children (TD) participated. Rasch-analysis was used to examine the rating scale and internal structure of the questionnaire. Test-retest reliability and construct validity was established. Intra-Class-Correlation (ICC), Standard-Error-of-Measurement (SEM) and Smallest-Detectable-Change (SDC) were calculated. Construct validity was determined by comparing HUH-scores between groups (UCP/NBPP/TD), within levels of lesion-extent in NBPP and Manual-Ability-Classification-System (MACS) levels in UCP.

Results: The development-cohort consisted of 322 children (mean age 6.7 years, UCP:n=131/NBPP:n=191) and the validation-cohort of 315 children (mean age 6.8 years, UCP:n=79/NBPP:n=181/TD:n=55). Eighteen hierarchically ordered bimanual items fitted a unidimensional model. HUH-scores ranged from -4.69 to +5.17 logits. Test-retest reliability was excellent (ICC=0.89). Agreement was high with a SEM=0.60 and SDC=1.66 logits. The HUH discriminated between groups (TD/NBPP/UCP): H(2)=118.985; 0.001, supporting construct validity. HUH-scores decreased with greater lesion-extent (r=-0.5) and higher MACS-levels (r=-0.4).

Conclusion: The Hand-Use-at-Home questionnaire has good psychometric properties and validly quantifies the amount of spontaneous use of the affected arm/hand in children with unilateral paresis, aged 3-10 years. The HUH questionnaire is a valuable addition to the current assessment of children with unilateral upper-limb paresis and provides clinicians with more insight in daily-life upper limb performance.
2.8 Assessing Arm Use in Children with Neonatal Brachial Plexus Palsy (NBPP)

L. Yang, S.H. Brown, M.E. Gatward, K.W.C. Chang
University of Michigan, Ann Arbor, United States of America

Objective: Assessment of patient-initiated function is critical in NBPP. Typical methods include range of motion (ROM), muscle strength, and the Mallet instrument: these clinician-elicited measures may not reflect spontaneous arm use in everyday settings. Recent advances in body worn sensor technology have made it possible to objectively measure arm movement in the real world, as we have previously demonstrated in adults. We aimed to demonstrate the utility of this technology in patients with NBPP.

Methods: Nine children with NBPP (11 ± 2 yo) were recruited sequentially from the University of Michigan Brachial Plexus Clinic. Participants wore accelerometers on each arm during waking hours for 7 consecutive days. Duration and magnitude of arm use were expressed as the ratio of affected to unaffected arm use. Ratios were correlated with traditional clinic-based assessments.

Results: Patient compliance and tolerance of the study devices were excellent. Mean duration of use ratio was 0.87, and mean magnitude of use ratio was 0.67. Duration and magnitude correlated strongly with shoulder flexion (r=0.87, p = 0.002), abduction (r=0.87, p = 0.002), and extension (r=0.70, p = 0.035). Surprisingly, no significant correlations were found with elbow or hand Active ROM.

Conclusion: We demonstrate in this proof-of-concept study that accelerometry is an ideal functional measurement as it captures and incorporates all WHO-ICF domains, contrary to typical clinician-elicited assessments. Similar to adults recovering from BPP, children with better shoulder ROM used the arm significantly more, thereby suggesting the importance of shoulder function to overall arm use in this population.
2.9 Outcome assessment for Brachial Plexus birth injury. Results from the iPluto worldwide consensus survey and update on PRO measures

W. Pondaag¹, H. Brown², E. Ho³, R. van der Looven⁴, M.J.A. Malessy¹
¹Leiden University Medical Center, Leiden, Netherlands
²Royal National Orthopaedic Hospital, Stanmore, United Kingdom
³Sick Kids Hospital, Toronto, Canada
⁴UZ Gent, Gent, Belgium

There is no consensus regarding strategies to optimally treat children with a brachial plexus birth injury (BPBI). Comparison of outcome data presented by different centers is impossible due to the use of (1) many different outcome measures to evaluate results; (2) different follow-up periods after interventions; and (3) different patient ages at the time of assessment. The goal of iPluto (international PLexus oUtcome sTudy grOup) was to define a standardized dataset which should be minimally collected to evaluate upper limb function in children with BPBI. This dataset must enable comparison of the treatment results of different centers if prospectively used.

Three rounds of internet surveys were used to reach consensus on the dataset. A Delphi-derived technique was applied using a nine point Likert scale. Consensus was defined as having attained a rating of 7/8/9 by 75% of the participants. A total of 59 participants from five continents participated in the Second and Third Rounds of the survey. Consensus was reached regarding four elements: (1) evaluation should take place at the age of 1/3/5/7 years; range of motion in degrees should be measured for (2) passive joint movement; (3) active range of motion; and (4) the Mallet score should be determined.

Consensus on how to assess and report outcome for BPBI was only reached on motor items from the "Body Function and Structure" domain. Consensus regarding PRO measures is the goal of the current survey rounds, of which the current status will be presented.
2.10 Beyond Movement for Children and Adolescents who have required OBPI Primary Repair: Does their movement impact their occupation and quality of life?

D.G. Gjertsen, C.D. DeMatteo, J.B. Bain, K.C. Colling, D.S. Stanbrook
McMaster Children's Hospital, Hamilton, Canada

Objective: Explore the relationship between movement, pain, occupational performance, self perception and quality of life (HRQoL) in school aged and adolescent clients who had primary repair of an obstetrical brachial plexus injury (OBPI)

Subjects: 16 participants aged 9-18 years, who had been followed prospectively in the OBPI clinic at McMaster Children’s Hospital.

Methods: Cross-sectional design using prospective assessments and retrospective chart review.

Measures: Body Function and Structures: Active Movement Scale (AMS), Mallet, Modified Pain Faces Scale (mPFS). Activities and Participation: Brachial Plexus Outcome Measure (BPOM), Self-Perception Profiles for Children or Adolescents (SPP), Kid Screen-27 (KS-27), Canadian Occupational Performance Measure (COPM).

Results: 11 male and 5 female with primary repair at 4-7 months. Statistically significant regression of movement (pre-surgery and current AMS: P=.001; 2 year and current AMS: P=.007). 73% of reported pain in their affected UE. BPOM significantly correlated with the AMS (=.798 P=.000) and Mallet (=.627 P=.012). 94% had occupational performance goals. SPP and KS-27 trended lower than peer related norms.

Conclusions: Movement regresses over time. Episodic pain is reported in the affected UE. Presence of Occupational Performance goals. HRQoL trended lower than age and gender norms.

Research and Practice Implications: Informs our assessment of this patient population over time aligning with ICF along with the work being conducted by national and international evidence based consensus groups (ie, iPLUTO). Guidance of larger sized, mixed method studies to further our understanding and treatment of OBPI and it’s impact over time.
### Scientific paper session 3: Brachial plexus adults/nerve general
Introduced and moderated by Michael Fox and Tim Hems

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Future directions for traumatic brachial plexus injury: Outcomes, natural history and nerve transfers

T.E.J. Hems
Queen Elizabeth University Hospital, Glasgow, United Kingdom

Traumatic brachial plexus injuries remain a cause of serious long term disability, with repair and recovery ultimately being limited by biological factors. I would identify three areas worthy of consideration in improving outcomes within current technology.

There is a need to agree on outcome measures. Development of patient rated outcome measures suitable for brachial plexus cases is showing promise. For motor function the medical research council scale has served us well because of its ease of use, but often the range of movement isn’t taken into account. As a minimum, outcomes should include formal measurement of muscle force and range of movement. In addition a record of co-contraction and independence of movement should be made.

We need to explore new methods for predicting the natural history of supraclavicular injuries before carrying out surgical repair. Historic series suggest that significant spontaneous recovery may occur at least after partial injuries affecting the upper plexus. This factor may even have affected recovery observed after nerve transfers. Assessing a lesion at exploration and deciding whether repair will improve the outcome remains difficult in some cases.

The trend towards repair using nerve transfers rather than nerve grafts, needs more critical evaluation. While nerve transfers have increased reconstructive options, some drawbacks, including co-contraction with function of the donor nerve, have been underreported. My own experience suggests that results for shoulder function have been improved by including accessory to suprascapular transfer, whereas outcomes for restoration of elbow flexion have not been substantially changed using nerve transfers.
3.1 Profile of Adult Traumatic Brachial Plexus Injury in Prof. Dr. Soeharso Orthopaedic Hospital Surakarta July 2013- September 2018

T. Sumarwoto
Prof Soeharso hospital, Sukoharjo, Indonesia

The incidence of the traumatic brachial plexus injury today continues to increase. Incidence ranged from 10% of peripheral nerve lesions and approximately 14% of neurologic lesions in the upper limbs is due to brachial plexus lesions. There are various kinds of management of traumatic brachial plexus modalities injury. A retrospective descriptive study was conducted on all adult patients with traumatic BPI in Prof. Soeharso hospital since July 2013 to September 2018. The evaluation was done on the patient demographic data, mode of injury, type, management. 13172 patients have administered in Prof. Soeharso hospital, an average of 3-4 cases per month, 129 men and 43 women. The commonest in productive age with a mean age was 31 years (range 16-63 years). The highest number of 105 cases due to traffic accident due to traction injury. Majority patient's arrival time: 3 months and 6 months post-trauma (70 cases). 51 cases with concomitant injury, and the most are humeral fracture 25 cases. Complete pre ganglioni type is the most common. External neurolysis mostly conducted as primary reconstruction (30 cases), while SAHA procedures mostly the highest secondary reconstruction procedures (55 cases). A research has conducted on the profile of patients who were diagnosed with traumatic BPI in Prof. Soeharso hospital during July 2013 to September 2018. This research can be a basic data for further research related to the traumatic BPI to provide input for improvement of the capability and outcome of the traumatic BPI management in Prof. Soeharso Orthopaedic Hospital Surakarta holistically.
3.2 Correlation of Magnetic Resonance Imaging (MRI Neurography) and Electrodiagnostic study findings with Intra-operative findings in post-Traumatic Brachial plexus palsy.

M. Thatte, N. Patel
Bombay Hospital, Mumbai, India
3.3 Brachial plexus injury incomplete type C5 C6 C7 treated with neurotization modified oberlin procedure in ortopedi hospital Prof. Dr. Soeharso Surakarta

T. Sumarwoto,
Prof Soeharso hospital, Sukoharjo, Indonesia

Brachial plexus injury (BPI) is a severe peripheral nerve injury affecting upper extremities, causing functional damage and physical disability. The most common cause of adult BPI is a traffic accident. One of type BPI is incomplete type which affected C5 C6 or C5 C6 C7 (Erb’spalsy). The motoric problem these patients are not be able to flex the elbow – extend the elbow (for C5 C6 C7) and also abduct the shoulder joint.

Neurotization is the gold standard for therapy. To overcome the inability flexion the elbow is neurotization to musculocutaneous nerve. Oberlin proposed the neurotization to the muscle branch to biceps of the musculocutaneous nerve from the ulnar nerve, fascicle to the FCU (Oberlin procedure). Later Mc Kinnon complete the neurotization to the muscle branch to brachialis of the musculocutaneous nerve from the median nerve, fascicle to the FCR (Modified Oberlin).

We overview modified Oberlin procedure in brachial plexus injury patient satour hospital Rumah Sakit Ortopedi Prof. dr. R. Suharso Surakarta Middle Jawa Indonesia from Januari 2015 – December 201. There are 19 patients brachial plexus injury upper type, consist 13 men and 6 women, the mean age is 30.3 years old, with the commone stage is at productive age. Average starting flexion the elbow is 6.8 months, with the motoric power (BMRC) are 3,4 and 5, the commonest is 3.

Neurotization is the gold standard therapy for Brachial plexus injury, and by neurotization there is a new hope for overcome inability flexion the elbow.
3.4 Leiden adult traumatic brachial plexus surgery series: outcome of 10 years

J. Groen, M.J.A. Malessy, W. Pondaag
Leiden University Medical Center, Leiden, Netherlands

OBJECTIVE The objective of this study was to assess the results of 10 year of brachial plexus surgery in Leiden following supraclavicular traction injury in adults.

METHODS All surgically treated adult patients with traumatic brachial plexus injury at the Leiden Nerve Centre between 2007 and 2017 were retrospectively analyzed. From 2009 onwards, the authors have strived to repair severe lesions as early as possible. Surgical finding and outcome in those who had undergone treatment within 2 weeks after trauma were retrospectively compared with results in those who had undergone delayed treatment. Patients treated with nerve grafting for C5 and C6 reconstruction were compared to patients with Oberlin transfers for reanimation of biceps function. The result of biceps muscle reanimation was the primary outcome measure. Secondary outcome measures were shoulder function, hand function and complications.

RESULTS A series of 131 patients with a minimum follow up time of 2 years was evaluated.

CONCLUSIONS result will follow after publication of data
3.5 Cervical exploration in total brachial plexus palsies: is it worth it?

C. Echalier¹, F. Teboul², B. Chevrier³, J.N. Goubier²
¹CHRU Besançon, Besançon, France
²Institute of Nerve and Brachial Plexus Surgery, Paris
³Imagerie médicale Grenelle, Paris

Objectives: There is currently no non-invasive and non-irradiating method for determining if a C5 and/or C6 root is graftable or not in complete brachial plexus palsies. The objective was to evaluate the reliability of the clinical examination coupled with MRI as a preoperative planning method.

Methods: We conducted a prospective study from 2013 to 2018. The inclusion criteria were to have a total brachial plexus paralysis and to be older than 18 years old. Claude-Bernard-Horner and irritative syndromes, phrenic and anterior serratus muscle paralysis were investigated. FIESTA 3D sequence MRI was performed for each patient. The surgical exploration of the C5 and C6 roots objectified if they were avulsed and, in case of rupture, assessed the possibility of grafting them.

Results: Twenty-seven patients were included. Serratus anterior testing had a specificity of 100% and its diagnostic efficiency was 78%. The presence of an irritative syndrome had a sensitivity of 100% and its diagnostic efficiency was 93%. MRI had a sensitivity, specificity and diagnostic efficiency of 89% all three. A decision tree to validate or not the possibility of grafting C5 and/or C6 has been developed with a sensitivity and negative predictive value of 100%.

Conclusion: This study approves the interest of this diagnostic method for a better operative planning. In total brachial plexus palsies, it could help to prevent the morbidity of cervical exploration.
3.6 Coaptation of full length n.phrenicus to n.axillaris

M. Kateva
Sofiamed, Sofia, Bulgaria

Objectives: N.phrenicus is a classic extra-plexus donor of axons for re-innervation of the muscles of the upper extremity by performing end-to-end or end-to-side microsurgical anastomoses with nerve-grafts (n.suralis, n.saphenus). A new method of direct neurotisation of n.axillaris with n.phrenicus was presented as n.phrenicus is taken endoscopically in its full length immediately before it sank into the diaphragm. M2 contractions(MRC) of m.deltoides was reported 4 months postoperatively. A major factor for successful neurotisation is time, most importantly, the donor / recipient nerve distance.

Methods: 5 adult patients with brachial plexus trauma are presented. Our approach to those with C5, C6, C7 avulsion and C8, Th1 neuropraxia was: 3 months after the trauma first stage of surgery treatment is presented- modified Oberlin method for restoration of elbow function is performed, as well as other nerve transfer was also carried out at the same stage: n.accessorius to n. suprascapularis. In the second stage neurotisation of n.axillaris is performed by taking full length of n.phrenicus.

Conclusions: M2(MRC) muscle contractions of m.deltoides are reported on the 4th postoperative month. The length of the intrathoracic n.phrenicus is 22 cm. This shortens the reinnervation time with 7-12 months. This is a revolutionary method of restoration of affected muscles after plexus brachialis trauma. A major factor in their successful neurotisation is the time. i.e., the donor / recipient nerve distance. The use of n.phrenicus with its full length as a donor shortens the re-innervation time of the impaired muscles.
3.7 Results of phrenic nerve transfer to the musculocutaneous nerve using video-assisted thoracoscopy in patients with traumatic brachial plexus injury: series of 28 cases

M. de Mendonça Cardoso, R.A.G. Amoreira Gepp
Sarah Network of Rehabilitation Hospitals, Brasilia, Brazil

Background: The phrenic nerve can be transferred to the musculocutaneous nerve using video-assisted thoracoscopy, aiming at the recovery of elbow flexion in patients with traumatic brachial plexus injury. There are few scientific papers in the literature that evaluate the results of this operative technique.

Objective: Evaluate biceps strength and pulmonary function after the transfer of the phrenic nerve to the musculocutaneous nerve using video-assisted thoracoscopy.

Methods: A retrospective study was carried out in a sample composed of 28 patients that were victims of traumatic injury of the brachial plexus from 2008 to 2013. Muscle strength was graded using the British Medical Research Council (BMRC) scale and pulmonary function through spirometry. Statistical tests, with significance level of 5%, were used.

Results: In total, 74.1% of the patients had biceps strength greater than or equal to M3. All patients had a decrease in forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1), with no evidence of recovery over time.

Conclusion: Transferring the phrenic nerve to the musculocutaneous nerve using video-assisted thoracoscopy may lead to an increase in biceps strength of M3 or greater (BMRC) in most patients. Considering the worsening of the parameters of spirometry observed in our patients and the future effects of aging in the respiratory system, it is not possible at the moment to guarantee the safety of the operative technique in the long term.
3.8 Geographical and population-based factors that can play a role in our BPI surgery results

M. Socolovsky¹, M. Malessy², G. Antoniadis³, G. Di Masi¹, G. Bonilla¹
¹University of Buenos Aires School of Medicine, Buenos Aires, Argentina
²Leiden University Medical Center, Leiden, Netherlands
³University of ULM, Argentina

BACKGROUND: Among other factors, like the time from trauma to surgery or the number of axons that reach the muscle target, a patient’s age, his body mass index and the country where he comes from might also impact the final results of brachial plexus surgery.

OBJECTIVE: To identify any correlations between age, body mass index, country of origin and the outcomes of BPI surgery.

METHODS: A literature analysis of some of our published series were analyzed. Univariate, univariate trend, and correlation analyses were conducted with patient age, body mass index, country of origin, time to surgery, type of injury, and number of injured roots included as independent variables.

RESULTS: A statistically significant trend toward decreasing mean strength in elbow flexion, progressing from the youngest to oldest age group, was observed. There were no differences by age group in final shoulder abduction range or the percentage achieving a good shoulder outcome. Similarly, BMI did predict shoulder abduction range of motion, but not percentage of strength or BMRC grade recovery for biceps flexion. Comparing patients many different countries shows different epidemiological trends.

CONCLUSION: Our data suggest that age, BMI and patient geographical origin are somehow linked to the outcomes of brachial plexus surgery. According to this results, extreme care should be taken at the moment of interpreting any published material on brachial plexus reconstruction.
3.9 Age as a Predictor of outcomes in Patients with upper Brachial Plexus injuries Undergoing Surgical Repair

R. Sharma, S. Gaba, M. Modi
Postgraduate Institute of Medical Education and Research, Chandigarh, India

Introduction: Brachial plexus injury (BPI) is a severe peripheral nerve injury affecting upper extremities, causing functional damage and physical disability. The aims of this study are to determine any correlations between age and the outcomes, satisfaction, and the degree to which patients’ expectations were met.

Method: 15 Patients who were seen for upper BPI were recruited. The patients were divided into two groups. Group A included patients from 18 to 40 years of age (n=10) and group B included patients 40 years of age (n=5). Detailed history and relevant clinical examination, motor examination based on the medical research council grading (MRC) to estimate limb and axial muscle strength done. Electrodiagnostic test were done preoperatively and post operatively at various time points.

Results: A statistically significant trend toward decreasing mean strength in elbow flexion, between the two groups, was observed. at six months and at 1 year postoperatively between the two groups. A statistically significant difference in shoulder abduction at 1 year postoperatively was seen.

Conclusion: Our data suggest that age is somehow linked to the outcomes of upper BPI with respect to elbow flexion and shoulder abduction strength. Increasing age is associated with steadily worsening outcomes, perhaps indicating the need for earlier surgery and/or more aggressive repairs in older patients. Early diagnostic assessment, correct timing of surgery and appropriate rehabilitation are crucial to obtain a rewarding outcome.
3.10 Brachial plexus lesions in shoulder dislocations and fractures of humeral neck in the elderly

U. Schnick, R. Boettcher
Unfallkrankenhaus Berlin, Berlin, Germany

Shoulder dislocation is a very common injury described mainly as a diagnosis of young people. Indeed about 20% of first-time dislocations occur in people older than 60 years of age, partly with severe complications like nerve lesions or axillary artery injuries.

In a retrospective analysis 31 patients with shoulder injuries in combination with nerve lesions and lesions of the axillary artery were listed between 2013 and 2018. 15 patients suffered on a traumatic nerve lesion. The nerve lesion occurred after reposition in 6 cases, postoperatively 5 times. The treatment of such nerve lesion was mainly conservative. A compression by hematoma caused by a lesion of the axillary artery in 3 cases or by anticoagulant therapy in 1 case led to additional nerve lesions. In these cases operative treatment were done followed by reinnervation.

The follow up from 1 month to 3 years was not really consistent – might be caused by the age of the patients. 6 patients were completely missed. In 11 cases incipient reinnervation was observed. In 1 case poor reinnervation remained despite neurolysis and in 5 cases only partial reinnervation was achieved. 8 Patients showed advanced reinnervation.

Results show a reinnervation in the majority. But deficits remained in a few cases. The greater focus on shoulder dislocations and their complications in younger people in the literature may lead to less attention to the higher risk and rate of complications in the elderly. A high awareness of the possibility of severe additional lesions is therefore important in treatment.
3.11 Brachial plexus injury as a complication of anterior shoulder dislocation is associated with long term functional deficits

Leeds Teaching Hospitals NHS Trust, Leeds, United Kingdom

Aims: Anterior shoulder dislocation is a common injury that may occur from a fall or other traumatic mechanism. Brachial plexus injury is an infrequent but important complication. Literature on functional outcomes is limited. We aimed to observe the recovery patterns of individuals with this injury.

Methods: Over two years, we monitored a cohort of consecutive patients with a brachial plexus injury due to anterior shoulder dislocation. Muscle power according to the Medical Research Council (MRC) scale and sensation was measured at baseline and until discharge. Median (with interquartile range, IQR) recovery are compared with the Sign-Rank test. The relationship between age and recovery is estimated by non-parametric regression.

Results: Twenty-eight patients were included. The mean age was 52 years (SD 14). Twenty-one injured nerves (26%) failed to improve their MRC score over a median follow-up of 5 months (IQR 3, 12; range 1-22 months). Advancing age increased the risk of failure to improve at least one point on the MRC scale, whereby every decade of life increased the risk of no improvement in MRC score by approximately 30%. There was no statistically significant improvement in sensation of any dermatomes over a median follow-up of 6 months (IQR 3, 9; range 1-23 months). The majority (85%) of sensory abnormalities failed to improve.

Conclusions: Anterior shoulder dislocation associated with a brachial plexus injury carries a significant risk of permanent nerve injury. Better recovery is observed in younger patients. All such patients should be referred for nerve rehabilitation therapy.
3.12 New strategy Surgery in C8T1 paralysis of the brachial plexus.

Z.B. Belkayar,
Clinique du Mont-Louis, Saint Ouen, France

The psychoanalytical paralysis of C8T1 remains the opening of long fingers and thumb
Tendon transfers to restore extrinsic volar aspect of the hand are classics
With the brachioradial on the long thumb flexor and the short radial extender of the carp on the deep flexors
A arthrodesis Trapézo metacarpal for stabilizing the thumb
Then a transfer of the biceps to the extensors of the long fingers and the thumb with a fasciae latta graft to restore the opening of
6 weeks of immobilization Elbow In bending
A short physiotherapy
The opening and closing of the hand is restoring with very good video results
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4.1 Transfer of pronator teres branch in C7-T1 brachial plexus injury: An electrophysiological and anatomic feasibility study

B. Xu
Huashan Hospital, Shanghai, China

Objective:
To screen new, feasible and safe donor nerve to strengthen the finger flexion recovery combined with the transfer of brachialis motor branch in C7-T1 brachial plexus injury.

Methods:
1. Electrophysiological study: The amplitude of the CMAP of each median nerve-innervated muscle after different nerve root stimulation was calculated and compared with each other in 18 patients undergone contralateral C7 nerve transfer.
2. Anatomic study: The median nerve and its muscular branches were exposed and dissected on 10 fresh cadaver upper extremities.

Results:
1. The pronator teres branch receives fibers mainly from C5 and C6.
2. The anatomic study revealed three branching patterns of pronator teres branch. Regardless of its branching pattern, there were constantly three twigs that entered the pronator teres and any of the three twigs was comparable to the anterior interosseous nerve in terms of length, diameter and number of myelinated fibers.

Conclusion:
The pronator teres branch can be used as a donor nerve to strengthen finger flexion in C7-T1 brachial plexus injury.
4.2 Dorsal scapular nerve as an additional neurotizer for better elbow stability and elbow flexion in complete adult brachial plexus palsy patients

L. Rasulic
Clinic for Neurosurgery, Clinical Center of Serbia, Belgrade, Serbia

Introduction
Dorsal scapular nerve (DSN) is a first to branch of the C5 nerve root before the latter courses into the brachial plexus (BP). This particular anatomical feature allows for the viability of the nerve in the most of cases with complete brachial plexus palsy (BPP), while also allowing its use as an additional neurotizer in BP reconstructive surgery.

Methods
This case series reviews 14 patients with complete BPP, and with a postganglionic lesion of C5 nerve root and an avulsion of all the other roots. In all patients we used DSN to the BLHT transfer to achieve better elbow stability and elbow extension. The sural and the medial cutaneous nerves of the forearm served as donors for grafts.

Results
Elbow extension satisfactory recovery occurred in 10 patients (71.4%) (M3 in 9 cases and M4 in one case) when DSN was used for grafting to BLHT. Satisfactory recovery of the elbow extension was achieved in 10 patients (71.4%) (M3 in 9 and M4 in one). None of the patients recovered hand and finger extension.

Conclusion
Usually forgotten or excluded in BP reconstructive surgery, the DSN has a potential for outcome improvement, standing as an independent neurotizer, with a minimal functional sacrifice. The transfer to BLHT allows for better elbow stability and some degree of elbow extension extension. In complete BPP patients, a combination with direct graft repair with the use of viable C5 proximal stump leads to the satisfactory useful functional recovery, especially in young patients.
4.3 Medial triceps and anconeus branch transfer for axillary nerve injuries: a case series

C. Romero, A.M. Monzon, G. Mallarino
Instituto de Ortopedia Infantil Roosevelt, Bogota, Colombia

Objective: To describe the outcomes of our experience of axillary nerve injury treated with medial triceps and anconeus branch nerve transfer.

Methods: Results: An average of eight months from injury to reconstruction was recorded. All patients recovered deltoid function, with no reports of loss on active extension of the elbow. In average, of 151° of shoulder abduction was recovered, with strength of M4 in seven patients, and M3 in one. Electromyography documented appropriate reinnervation in all patients. The patients reported overall satisfaction, and scarce morbidity from the donor area. 1872 axons were found in the medial triceps and anconeus branch.

Results and Conclusions: Conclusion: Good results and low donor-site morbidity was found with transfer of the medial tricipital and anconeus brach for axillary nerve injuries via a posterior approach. PRO's evaluated in this study seem to support this theory. An adequate recuperation of deltoid muscle was registered clinically and electromyographically. These findings seem to point out that this is a useful technique when treating this kind of peripheral nerve injury.
4.4 Addition of pectoralis major innervation to the Wang Strategy

A.G. Bhatia, P. Doshi
Deenanath Mangeshkar Hospital, Pune, India

Wang Shufeng reported his technique of direct transfer of the opposite C7 to the lower trunk in C5T1 avulsions in 2013. We have adopted his strategy since October 2013. The procedure involves sectioning of the pectoral nerves to aid mobilisation of the lower trunk. The supraspinatus muscle is the only motor of the shoulder that is innervated. Since November 2014, we chose to connect the medial cutaneous nerve of the arm to one or more of the divided pectoral branches in order to harness the growing axons from the opposite C7 to innervate the pectoralis major. So far, we have done this in 27 patients. We have followup longer than 16 months in 16 of these patients and 11 of them regained some pectoral function. Contraction of the ipsilateral pectoralis major is noted before that of the biceps and is activated by resisted adduction of the opposite arm or by resisted triceps action. The recovered pectoralis major contributes to the stability of the shoulder. In addition, appearance of pectoral contraction serves to signal the progress of the growing axons along the lower trunk. It also indicates the integrity of the repair to the opposite C7.
4.5 Free neurovascular muscle transplantation – a report of more than 200 cases  M. Becker and F. Lassner

M. Becker  
Pauwelsklinik Aachen, Aachen, Germany

1203 patients with lesions of the brachial plexus have been operated between 2/04 and 12/17: In 220 cases free neurovascular muscle transplantation was performed. Minimal time interval for evaluation was nine months.

In the majority of cases (203) the gracilismuscle was used for the transfer, in 17 patients with combined soft tissue defect the latissimus dorsi muscle.

In 94 cases muscle transfer was used for biceps substitution. In 80 cases function defect of the forearm were the indication for neurovascular muscle grafting. 11 patients demonstrated with facial paralysis. In the remaining cases duncional defects of the shoulder and the lower leg were reconstructed.

Reinnervation was achieved by different procedures according to the different levels of nerve lesions. They vary from direct nerve suture to serial, combined nerve grafts with a total length of more than 50cm. In these cases nerve grafting was performed in the first step, after biopsy the neurovascular transfer was performed. Age of the patients was from 2,5 to 65 years.

Nine muscle grafts were lost, four by vascular reasons and five by missing reinnervation. Most common problem (7%) was a seroma at the donor site.

Best results were achieved with defined motor nerve donors, even in longer distances. Nerval reinnervation from mixed donors showed more variety concerning muscle power and endurance.
4.6 Finding a standard – Results in brachial plexus surgery for the adults

R. Boettcher¹, U. Schnick¹, T. Hems²
¹Unfallkrankenhaus Berlin, Berlin, Germany
²NHS Greater Glasgow and Clyde Victoria Infirmary, Glasgow, United Kingdom

The limited number of cases in surgery for traumatic brachial plexus injuries in the adults often does not allow statistically well defined conclusions. Statements concerning influencing factors such as age, delay between trauma and surgery and concurrent surgical concepts are of low evidence in most single series. Metaanalyses are a common tool used to solve this problem. But up to now metaanalyses in brachial plexus injuries were limited by the restricted comparability of published results. Most studies only present one item, such as range of motion, force, function or satisfaction. Different outcomes and documentation are used. Statistical analyses follow unequal rules. Several well prepared protocols for comprehensive follow-up are established, but their use seems not to be feasible beside prospective controlled studies. The presentation will introduce the different protocols and focus on the problem of standardizing results for pain, sensory, range of motion, force and function in consideration of former contributions at the Narakas-meetings. Special attention will be given to feasibility taking into account limited conditions in different countries and cultural requirements. The presentation can only be the starter for an ongoing discussion with the aim to compromise in developing a recommended standard outcome assessment.
4.7 COMBINE - Core Outcome Measures in Brachial plexus INjuries

C. Miller
National Institute of Health Research, Birmingham, United Kingdom
4.8 Effectiveness of rehabilitation in traumatic brachial plexus injuries: retrospective study of 102 cases assisted in a single hospital in Latin America


Introduction / Objectives: Traumatic brachial plexus injuries may be disabling and there are few studies in the literature that evaluate the effectiveness of rehabilitation. The main objective of this study was to analyse the influence of interdisciplinary rehabilitation on functional capacity and return to work/study, as well as level of satisfaction with treatment after traumatic brachial plexus injury.

Material and methods: A retrospective study of 102 patients admitted to a single hospital in Latin America between June 2012 and May 2017. The rehabilitation interventions, self-perception of what influenced return to work, functional capacity (DASH) and satisfaction with treatment (visual analogic scale, 0-10) were analysed. SPSS software was used for statistical analysis and a considered level of significance of p 0.05.

Results: Functional capacity improved after rehabilitation (p 0.05), especially in men with incomplete lesions. Return to work/study occurred in 74% of the population. Strength and functional capacity improvements were predictors for return to work/study (p 0.05). Furthermore, age, gender, educational level, type of work and level of satisfaction differed between patients who returned and did not return. Satisfaction was graded between 8.9 and 9.5 in 95% of the cases. Twenty-nine patients answered the question regarding self-perception of what influenced return to work. They indicated “necessity”, “my desire”, “rehabilitation” and “not become depressed”.

Conclusion and perspectives: Interdisciplinary rehabilitation influenced functional capacity and return to work or study. It should thus be part of the treatment plan in patients with traumatic brachial plexus injuries.
4.9 Rehabilitation of Upper Extremity Nerve Injuries Using Surface EMG Biofeedback: Protocols for Clinical Application

O.C.A. Aszmann, A. Sturma, J. Mayer, C. Prahm, L. Hruby
Medical University of Vienna, Vienna, Austria

Introduction:

Motor recovery following nerve transfer surgery depends on the successful reinnervation of the new target muscle by regenerating axons. Cortical plasticity and motor relearning also play a major role during functional recovery. Successful neuromuscular rehabilitation requires detailed afferent feedback. The aim of this paper was to present the value of structured rehabilitation protocols.

Materials & Methods:

Patient group 1 included nerve injury patients who received nerve transfers to restore biological upper limb function, while group 2 comprised patients where biological reconstruction was deemed impossible and hand function was restored by prosthetic hand replacement. The rehabilitation protocol for group 1 included guided sEMG training to facilitate initial movements, to increase awareness of the new target muscle and to facilitate separation of muscular activities. In patient group 2 sEMG biofeedback helped identify EMG activity in biologically “functionless” limbs and improved separation of EMG signals upon training.

Results:

Functional outcome measures were assessed with standardized upper extremity outcome measures. The British Medical Research Council scale for group 1 and Action Research Arm Test for group 2. Before actual movements were possible, sEMG biofeedback could be used. Patients reported that this visualization of muscle activity helped them to stay motivated during rehabilitation and facilitated their understanding of the re-innervation process. sEMG biofeedback may help in the cognitively demanding process of establishing new motor patterns.

Conclusion:

After standard nerve transfers individually tailored sEMG biofeedback can facilitate early sensorimotor re-education by providing visual cues at a stage when muscle activation cannot be detected otherwise.
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5.1 Which tissues contribute to the internal rotation contracture in the BPBP shoulder?

K. Jönsson, T. Hultgren
Södersjukhuset, Karolinska Institutet, Stockholm, Sweden

Internal rotation contracture with or without concomitant incongruence of the shoulder joint is a major sequel of brachial plexus birth palsy. In the early twentieth century authors gave considerable attention to pinning down exactly which anatomical structures caused the contracture. Since then many surgical techniques have been proposed, but there is still no consensus regarding the optimal treatment of these children. The main purposes of this study were; to investigate which anatomical structures are responsible for the contracture, what it takes to release it and to present a detailed account of the method used in our center for 20-some years.

Nineteen consecutive patients with a mean age of three years (9 months-14 years) were enrolled, the indications and procedure remaining unchanged to our previously published method. As the surgery proceeded, an assistant to the senior surgeon used a goniometer and a ruler to measure the progress in outward rotation of the shoulder in adducted and abducted position as well as the lengthening in the subscapularis (SS) tendon and the passive excursion of the SS tendon.

Excision of the enlarged part of the coracoid process, division of the coracohumeral ligament and division of the cranial half of the SS tendon had a marginal effect on the contracture. Adequate release was achieved only when the entire SS tendon had been divided. Additionally a limited capsulotomy was required only in cases where the humeral head was relocated.
5.2 Shoulder and Elbow Function following the Sup-ER Protocol in Children with Birth Related Brachial Plexus Injuries: A Pilot Study

L. Yefet¹, D. Bellows², K. Durlacher², S. Hynes¹, R. Courtemanche¹, M. Bucevska¹, C. Verchere¹
¹University of British Columbia, Vancouver, Canada
²BC Children's Hospital, Vancouver, Canada

Background: Consensus regarding the optimal management of birth-related brachial plexus injuries (BRBPI) has not been achieved with various treatments including physiotherapy, occupational therapy, and surgery. Our group developed a protocol that repositions the shoulder into supination and external rotation (Sup-ER), which helps restore supination and external rotation by two years of age. However, the longer-term outcomes of internal and external rotation have not been reported.

Methods: This cross-sectional cohort study examined 16 children older than 4 years of age with severe BRBPI who were treated with the Sup-ER splint. Shoulder and elbow function were measured by the ABC loops and a modified Mallet scale. Additionally, the passive and active range of motion of internal rotation, external rotation, supination, pronation, elbow flexion and elbow extension, as well as internal and external rotation strength were examined.

Results: All active movements were statistically significantly lower in the affected arm compared to the unaffected arm, except for elbow flexion. Passively, there were no statistically significant differences between the affected and unaffected arms in internal rotation and supination. Strength in internal and external rotation was weaker in the affected arm, with internal rotation having a relatively larger strength deficit.

Conclusions: Despite differences in anatomic ranges of motion between the affected and unaffected arms, the ranges were within functional limits. The relative weakness in internal rotation is less than what is described in the literature.
5.3 A new surgical technique for internal shoulder contractures secondary to obstetric brachial plexus injury: an anterior coracohumeral ligament release

C. Sarac, S. Hogendoorn, R.G.H.H. Nelissen
Leiden University Medical Center, Leiden, Netherlands

Background: Obstetric brachial plexus injuries (OBPI) result from traction injury during delivery, 30% of these children sustain persisting functional limitations related to an external rotation deficit of the shoulder. The aim of this study was to compare the intraoperative gain in external rotation after a posterior subscapular release and an anterior coracohumeral ligament release.

Methods: A prospective study on 102 children with an internal rotation contracture of the shoulder who received either a posterior subscapular release (posterior skin incision along the medial border of the scapula of 3-5cm) or an anterior (5mm skin incision) coracohumeral ligament release between 1996 and 2010. After general anesthesia, abduction and external rotation, in adduction and abduction, were measured before and after the surgical release.

Results: After a posterior subscapular release, the intraoperative external rotation in adduction improved with a mean of 64 degrees (95%CI: 54 – 74, 0.001) and with 41 degrees (95%CI: 32-49, 0.001) in abduction. After an anterior coracohumeral ligament release, external rotation in adduction increased with a mean of 61 degrees (95%CI: 56 – 66, 0.001) and increased 42 degrees in abduction (95%CI: 39-45, 0.001). Differences between these two groups were not statistically different.

Conclusion: The anterior release technique shows comparable results as the posterior subscapular release. And since it is performed through a smaller incision of 5mm, this is our preferred method to increase passive external rotation.
5.4 Minimally Invasive Subscapularis Release: A Novel Technique and Results

M. Shah, N. Nischal, P. Tejas
Orthokids Clinic, Ahmedabad, India

Introduction: Subscapularis is considered as the prime element of internal rotation contracture in patients with residual Brachial Plexus Birth Palsy. We describe here a novel minimally invasive technique of Subscapularis release & its results.

Material & Methods: Between 2013 to 2016, Forty-five patients underwent Subscapularis Slide through a centimetre incision along the medial border of scapula. Procedure was termed as "Minimally Invasive Subscapularis Release" (MISR). A concomitant conjoined Latissimus Dorsi and Teres Major transfer was performed. Thirty-three patients (average age - 5.6 years) with minimum follow up of one year were included in this study. Axial imaging to assess Glenohumeral deformity were available for twenty patients. Average clinical follow up of patients was 3 years.

Results: Mean improvement in passive external rotation was 64° and in active external rotation was 53° (p 0.001) at 3 months, which was maintained at final follow up. Average shoulder abduction improved from pre-operative 101° to post-operative 142°. Aggregate five-point Mallet Score improved from 13 points (range, 11-16) preoperatively to 18.8 points (range, 17-22) post operatively. No patient developed external rotation contracture. The results were comparable to other existing techniques. Safety zones to avoid injury to important neurovascular structures while performing MISR were determined through cadaveric dissection.
5.5 Management of shoulder internal rotation limitation in obstetrical palsy

A. Aydin
Istanbul medical faculty, Istanbul, Turkey

Muscle imbalance in a growing child can lead to bone and joint deformities. Obstetric palsy patients with incomplete recovery have glenohumeral joint problems because of imbalance between shoulder adductor and internal rotator (IR) muscles; abductor external rotator (ER) muscles.

Since to improve shoulder abduction and ER, tendon transfers are commonly used, postoperative transient loss in internal rotation is expected. But some patients could not get preoperative IR functions, long after the operations. Also there are some nonoperated patients whose main problem is internal rotation limitations. We operated on these two group of patients to achieve better internal rotation function.

Fourteen patients had operation to improve shoulder ER and Abduction but 15 patients did not have neither nerve nor palliative any operation before and had IR limitations preoperatively. During operation, posterior incision above spine of the scapula was performed, supraspinatus, infraspinatus and teres minor muscles, and acromion bone were encountered. We did not cast or use orthosis for the patients postoperatively. At 3rd day postoperative rehabilitation program active range of motion exercises were initiated. Average age of the children was 6.3 years and The average follow-up period was 21 months. The preoperative values in terms of IR were 2º and postoperatively 20º. Degree of abduction was mean 136 before the surgery. After surgery, it decreased to 105º but with therapy it caught up preoperative values and all children improved shoulder IR function. We operated on patients with limited shoulder IR, and achieved better hand to midline and back functions.
5.6 Shoulder release and tendon transfer for neonatal brachial plexus palsy: gains, losses, and midline function

R. Tse, W. Adidharma, S. Lewis, K. Liu, M. Osorio
Seattle Children’s Hospital, Seattle, United States of America

Persistent deficits of external rotation are often treated by shoulder release and tendon transfer. Gains in external rotation have previously been emphasized whereas losses of internal rotation are poorly documented. Given that inability to reach midline has functional consequences the losses associated with surgery need to be better understood. The purpose of this study was to assess changes in movement, function, and self-reported outcome after surgery.

Methods: Retrospective review of prospectively collected measures for 30 consecutive patients was conducted. Mean follow-up was 48 months. Significant changes were assessed by t-test and Wilcoxon rank sum (0.05).

Results: Active motion increased for external rotation (AMS 1.5 to 2.9 and AROM 2 to 38) and abduction increased (AMS 5.5 to 6.2 and AROM 105 to 140); while internal rotation decreased (AMS 7.0 to 5.7 and AROM 73 to 67). The total arc of motion was unchanged. While there were increases in all other domains of the Mallet scale, there was no change in hand-to-spine and there was a decrease in hand-to-belly (3.8 to 3.1). There were improvements in Brachial Plexus Outcome Measure (BPOM) task-based domains and in self-reported outcomes of appearance and function (18.3 to 23.0). Inability to reach midline occurred in 3 patients with more severe palsies (type 2 or worse). No specific predictors could be identified.

Conclusions: Increases in external rotation were accompanied by losses of internal rotation with inability to reach midline occurring in 10%. Despite the losses there were overall improvements in function based upon Mallet and BPOM scores.
5.7 Tendon and muscle anomalies around shoulder

A. Aydin, Turkey
Istanbul medical faculty, Istanbul, Turkey

Our algorithm concerning shoulder external rotation (ER) limitation in an obstetric palsy patient, under 1 year of age, comprises MRI study of the shoulder, and clinical testing. If the glenohumeral joint is subtle and limitation is less than 30 degrees we perform botulinium injection to subscapularis, latissimus dorsi and pectoralis major muscles. If we observe posterior subluxation, glenoid displasia and ER limitation is advanced, we perform anterior and posterior release.

During surgery of the children of whom we perform posterior release or tendon transfer; we observe muscle/tendon anomalies and variations occasionally. Tendon anomalies were mostly originate from conjoint tendon and heading to humerus looking like thickened facial bands. These anomalies are far common than muscle anomalies and we came across one third of surgical cases. But they definitely limit shoulder abduction and cannot be addressed by botulinium toxin injection.

The muscle anomalies can be aberrant muscle from latissimus dorsi to pectoralis major and this muscle also prevents passive full range shoulder abduction. We observed 8 cases out of hundreds of operations.

Literature mentions about muscle variations around shoulder like axillopectoral muscle, axillary arch muscle etc and brachial plexus surgeons but be aware of these extra anatomic structures which can be the cause of botulinium injection or tendon transfer failure.
5.8 25-Year Experience with the Subscapularis Slide for Correction of Internal Rotation Contracture in Brachial Plexus Birth Palsy

J.B. Bookman¹, M.A. Aversano¹, J.A.I.G. Grossman², A.P. Price¹

¹NYU Langone Medical Center, New York, United States of America
²Nicklaus Children’s Hospital, Miami, United States of America

The subscapularis slide involves the release of the subscapularis muscle off of its scapular origin while avoiding the need for additional anterior releases. We report on our 25 year experience with this technique. 104 patients (57 female, 47 male) underwent the subscapularis slide procedures for internal rotation contracture in neonatal brachial plexus palsy over a 25-year period from 1992 to 2017. This was performed in association with other procedures including microsurgical brachial plexus reconstruction, tendon transfers for external rotation, botulinum toxin injections, and or humeral osteotomies. Patients were followed up for an average of 5.1 years post operatively. Mean age at operation was 3.8 years. Records were assessed for final range of motion and need for any additional procedures.

At initial presentation, patients had an average of 101 degrees of forward elevation (range 30-170) and 13 degrees of external rotation (range 20-90). 20 patients (19%) had prior brachial plexus reconstruction, 23 patients (22%) had concurrent brachial plexus reconstruction, and 61 (59%) did not have any brachial plexus surgery. Intraoperatively, full passive range of motion as compared to the contralateral shoulder was achieved in all cases. At final follow up, average external rotation was 43 degrees (range 0-85) and forward elevation was 133 degrees (range 45-180). The subscapularis slide technique can be effectively used in the management of internal rotation contracture after brachial plexus birth injury. A functional range of forward elevation and external rotation can be reasonably achieved in these patients with the use of this technique.
5.9 Gleno humeral inferior release combined with latissimus dorsi transfer to restore shoulder abduction on brachial plexus obstetrical palsy

M.N. Nouara, A.K. Korchi
Djihan hana clinic, Algiers, Algeria

At the end of the recovery period in obstetric palsy of the brachial plexus, the shoulder abduction deficit remains frequent. A stiffness of abduction at the glenohumeral joint by retraction of the axillary elements is associated in the majority of cases. I achieved for 3 years in 47 cases an inferior release of the gleno humeral joint associated with a transfer latissimus dorsi muscle the lower release has the following steps: - Axillary Approach and section of fibrous bands between triceps and latissimus dorsi muscles - Dissection of the latissimus dorsi muscle which is separated from the teres major and its severed tendon at its humeral insertion - Section of teres major muscle - Section of the insertion of the long portion of the triceps - Opening of the inferior capsule - axillary Z-plasty perform a transfer of latissimus muscle on the posterior side of humeral head the shoulder is immobilized with thoracic and shoulder brachial splints in maximum abduction position for 15 days physiotherapy is started immediately after removal of the immobilization with repeated movements several times a day at home and at the physiotherapist for results, important improvement of abduction is obtained in 31 cases and abduction didn't change in 7 cases will show videos of pre and post operative status of patients and a review of literature.
5.10 Obstetrical brachial plexus injuries, a long-term prospective study on the outcome of external rotation plasties of the shoulder

Leiden University Medical Center, Leiden, Netherlands

Background: Obstetric brachial plexus injuries (OBPI) result from traction injury during delivery, 30% of these children sustain persisting functional limitations related to an external rotation deficit of the shoulder. Our aim was to evaluate different soft tissue procedures to improve external rotation during 5-year follow-up.

Methods: 105 children with an internal rotation contracture of the shoulder received either I) an internal contracture release or II) an internal contracture release in combination with a tendon transfer for active external rotation. Prospective functional assessment of the shoulder was performed preoperatively and postoperatively at 6 weeks, 3 months and annually thereafter.

Results: The internal contracture release showed an improvement in passive external rotation in adduction of 29 degrees and of 17 degrees at one year follow-up and of 25 degrees and 15 degrees at five years.

The internal rotation contracture release combined with an active tendon transfer showed an improvement, compared to the preoperative state: active external rotation in adduction were: 75 degrees and 50 degrees at one year follow-up; 65 degrees and 40 degrees at five years.

Conclusion: Young children with OBPI without spontaneous functional recovery of the shoulder benefit from soft tissue procedures according to the presented strategy. The policy of only a passive correction of the internal rotation contracture release resulted in improved active external rotation in 54% of the youngest age group. In the older age group, improvement of both active and passive range of motion were clinically relevant and sustained during 5-year follow-up.
5.11 Twenty-year experience of arthroscopic subscapularis release for internal rotation contractures secondary to neonatal brachial plexus injury: clinical and radiographic outcomes

M. Pearl
Kaiser Permanente, LAMC, Los Angeles, United States of America

Intro:

The internal rotation contracture (IRC) secondary to neonatal BPI is common and alters glenohumeral development in most cases. A variety of treatment options have been reported on with clinical success. It remains unclear which surgical approach optimally improves function and glenohumeral development. This report reviews a 20 year experience of arthroscopic contracture release looking to identify factors associated with good/excellent results and differentiate them from those that seemingly exchanged one problem for another or even made patients worse.

Methods:

Twenty-five children for whom pre-operative and long term clinical and MRI follow up were available before and after arthroscopic subscapularis release were retrospectively reviewed. Conventional measures of range of motion and glenohumeral anatomy on imaging were analyzed. Surgical release of the tendinous portion of the subscapularis, the anterior joint capsule and rotator interval tissue inclusive of the coracohumeral ligament was performed on all children, with or without transfer of the latissimus dorsi tendon to the posterior greater tuberosity (9/25). The mean age at surgery was 3.7 years old, range 0.7 to 8.3 years old. Passive external rotation (ER) with the arm adducted by the side measured under general anesthesia (intra-op) was -30°. All children had near full passive elevation (mean 135°) under anesthesia. Active elevation pre-operatively averaged 110° (range 40° to 150°). Pre-operatively, 21 children had pseudoglenoids of varying severity and four had Posterior/Concentric glenohumeral joints on MRI.

Results:

All children showed gains to near normal range in active and passive ER, both with the arm at the side and in an elevated position. All children showed reduced range of internal rotation (IR) after release that was functionally well compensated in 15 cases, challenged midline function in 10 cases, and led to an internal rotational osteotomy of the humerus in one case. Active elevation was not changed from pre-op except in one child who lost 30° elevation after combined arthroscopic release and latissimus transfer at age 4.6 yo for a -60° internal rotation contracture and severe pseudoglenoid. For children with the longest follow up (> 5 years), range of motion changed considerably over time resulting in decreased ER, improved IR and usually reduced elevation.

Follow up MRI or CT (two cases) was done at an average of 3.3 years post index surgery. Glenohumeral alignment (PHHA) normalized in all but one shoulder that was essentially unchanged. Glenohumeral morphology also improved in all but that one child, resulting in rounder humeral heads articulating with glenoids of improved concavity. Glenohumeral contact patterns and orientation essentially reversed from pre-op, repositioning the humeral articular surface so that its
posterior aspect, rather than anterior aspect, articulated with the glenoid. This re-orientation of the humeral head normalized half (13) of the glenohumeral joints. In the other 12 children, the reoriented position of the humerus was in maximal external rotation. This was functionally well compensated in most but resulted in functionally disabling external rotation contractures in a few, the majority of whom were operated after age three years old.

Conclusion:

This review found that most children with IRC from birth palsy were improved by arthroscopic release. Clinical outcomes were excellent in some, clearly improved in others but with an apparent exchange of ER range and function for IR range. This exchange of ER for IR occurs at, and can be visualized, at the glenohumeral joint. External rotation consistently improves from arthroscopic release, as does the appearance of glenohumeral anatomy. Together these improvements will score highly on conventional clinical and radiographic measures – Mallet score, PHHA, etc. Active elevation was not appreciably altered from preop, although improved ER led to a marked improvement of the child’s ability to reach overhead.

No clear factors were identified in this cohort to predict which patients would have the best outcome. Younger age at the time of surgery was beneficial. In order to advance our understanding and treat patients more effectively continued efforts are necessary to better differentiate patterns of injury and sequela that may represent different patient populations better treated by different methods.
5.12 Short and Long Term Outcomes after Treatment of Shoulder Subluxation in Birth Brachial Plexus Palsy

M. Osorio, R.T. Tse, S.L. Lewis
University of Washington/Seattle Children’s Hospital, Seattle, United States of America

Background: Methods vary for timing of evaluation shoulder subluxation, modality used for detection and type of intervention. The purpose of this study is to describe the incidence and clinical outcomes after early detection and intervention for shoulder subluxation.

Methods: Retrospective chart review with 64 patients included. Patients divided into three groups based on alpha angles from shoulder ultrasound: normal, abnormal + no intervention, and abnormal + intervention. Intervention group received onabotulinum toxin A +/- casting. Outcome measures included passive range of motion external rotation (PROM-ER), Active Movement Scale (AMS), alpha angle, Waters score on MRI, and need for tendon transfer.

Results: Initial ultrasound performed at mean 16.6 weeks of age. Shoulder subluxation found in 89%. Mean alpha angle for normal group was 24.5°, abnormal + no intervention was 40.2° and abnormal + intervention was 56.4°. Only abnormal PROM-ER predicted abnormal alpha angle. Eighty-seven percent of abnormal + intervention group had normal alpha angle after intervention (mean alpha angle 25.8°). Fifty percent of normal group, none of abnormal + no intervention group, and 32% of abnormal + intervention group required tendon transfer. Pre-operative MRIs were compared and 50% of normal group compared to 54% abnormal + intervention group had Waters score = 3.

Conclusions: Shoulder subluxation occurs in the majority of patients by 4 months of age and in the absence of clinical signs. This is adequately treated with botulinum toxin and casting, but this does not appear to have an effect on the long term development of the glenohumeral joint.
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6.1 Long-term Results of Isolated Latissimus Dorsi Transfer in Brachial Plexus Birth Palsy

A. Price, L.S. Santiesteban
NYU Langone Orthopedic Hospital, New York, United States of America

Purpose: This is a retrospective analysis of the longterm results of isolated latissimus dorsi transfer.

Methods: From 200 to 2010, 52 isolated latissimus dorsi transfers were performed for internal rotation contractures in patients with recovery of infraspinatus power less than 2/5 and teres minor recovery greater than or equal to 4/5, using the Medical Research Council (MRC) scale. Inclusion criteria for the study were patients with a congruent glenohumeral joint, who received an isolated latissimus dorsi transfer into the infraspinatus in addition to release of the internal rotation contracture of the shoulder with greater than 5 years follow-up. 22 patients satisfied the inclusion criteria: 9 global palsies and 13 Erb’s palsies. There were 13 females and 9 males. Failure was defined as a return of the internal rotation contracture and a clinically apparent clarion sign.

Results: The average follow-up was 11 years, ranging from 7.5 to 15.9 years. All 9 global palsies maintained adequate external rotation without clarion sign. 5 of 13 Erb’s palsies failed isolated latissimus dorsi transfer and subsequently required teres major transfer, rotational osteotomy or by patient’s preference, acceptance of their functional status. In these 5 failures, the period from latissimus dorsi transfer to failure average 6.6 years, ranging from 3.4 to 9.5 years.

Conclusion: We recommend isolated latissimus dorsi transfer for global palsy patients who have infraspinatus weakness. However, given the longterm unpredictable and high failure rate in patients with Erb’s palsy, simultaneous latissimus dorsi and teres major transfers are recommended.

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Orthokids Clinic, Ahmedabad, India

Introduction:
A subset of patients with residual Obstetric Brachial Plexus Palsy (OBPP) suffer from limited shoulder abduction in the presence of good active shoulder external rotation. This restricted abduction in the presence of preserved deltoid girth; innervation is attributed to anterior shoulder instability secondary to shoulder internal rotator weakness. A novel strategy to improve anterior shoulder stability is described; early results are discussed.

Materials & Methods: 22 patients with residual OBPP with active external rotation (ER) more than 45° (arm adducted) and abduction less than 90° were subjected to procedure. Lateral reinsertion of both ends of Clavicular part of Pectoralis Major was done preserving its neurovascular pedicles. Conjoined Teres Major - Lattisimus Dorsi transferred to Infraspinatus if ER was less than 90° (arm abducted). Shoulder range of motion and Modified Mallet Scores were noted before and average 1.5 years after the surgery.

Results: Average age of patients was 6 years (range 2 - 15 years). Fourteen patients had Narakas -1 injury and four had Narakas - 3. Average shoulder abduction improved from 76° to 138°. Average gain in Shoulder abduction was 62° (81.5%). 18 out of 22 patients (87%) achieved Mallet Score IV or V. Aggregate Mallet Score improved by 3.4 points. Average active Shoulder External rotation improved from 46° to 77°.

Conclusion: Trans positioning of Clavicular part of Pectoralis Major seems an impressive strategy to improve shoulder abduction movement in patients with weak shoulder internal rotation and anterior shoulder instability.
6.3 Transfer of the trapezius muscle to restore external rotation in OBPL

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Hopital Mohamed Boudiaf Medea Algerie , Medea, Algeria

Objectifs

L’objectif de cette étude est de réanimer la rotation externe active, améliorer la stabilité de l’épaule et minimiser la déformation osseuse secondaire. Ceux-ci permettent une grande amplitude du mouvement bras et avant-bras.

Matériel et méthode


Résultat

le gain moyen en rotation externe active et passive était de 40° (30° à 70°). Ces valeurs sont statistiquement significatives rapport à leur état préopératoire. Dans le postopératoire période, il y a eu une amélioration significative du signe de clairon. La force de rotation externe a été cotée M3 + chaque patient étant capable de toucher leur abdomen, les derniers degrés de mouvement de rotation interne étaient dans la scapulo-thoracique, La force de la rotation interne a été marquée comme M4 pré et postopératoire chez tous les patients.

Conclusion

Transfert de trapèze inférieur pour la réanimation de la rotation externe produit un résultat satisfaisant en ce qui concerne la fonction et la stabilité, c’est technique pratique, simple, sans complications et fiable.
6.4 Derotation osteotomy of the humerus in patients suffering from obstetrical brachial plexus palsy – effects on kinematics of the upper extremity

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Patients with untreated upper brachial plexus lesion (OBPL) frequently develop an internal rotation contracture of the shoulder, deficient active shoulder abduction and especially external rotation. The humeral derotation osteotomy combined with muscle transfers is one of the most common secondary reconstructive procedures to improve upper limb function. 12 children (7 girls, 5 boys, aging 5-13, mean 9 years) with secondary deformities following an OBPL were investigated before and after humeral derotation and muscle transfers. 3 patients underwent derotation osteotomy only, 5 had additionally muscle transfers and 4 an additional release of internal rotators. An optoelectronic motion analysis system was used for assessment.

Results of the motion analysis document dynamic improvement of the involved shoulder, but not to normal range. While elbow flexion was not influenced even pronosupination increased. The average effective external derotation of the upper arm was 49°, from 57 to 9°, compared with an average of 27° resting position of the humerus for healthy probands, meaning an overcorrection which clinically caused loss of some useful internal rotation based ADL function. Concerning the different procedures there was no difference between the 3 groups. Derotation of the humerus produced functional improvement at the shoulder and influenced kinematics of the whole upper extremity. The actual amount of humerus-derotation was about 15-20° too high, meaning a change in amount of derotation for the future. The missing statistical difference between the 3 surgical groups gives indication to proceed with an individualised surgical strategy according to the preoperative presentation of the patient.
6.5 Glenohumeral Fusion in adults with sequelae of obstetric brachial plexus palsy: A Report of 8 Cases

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Objective: Deformation of the gleno-humeral joint resulting from obstetrical brachial plexus palsy includes glenoid retroversion and loss of the humeral head sphericity. As a result, patients may show posterior dislocation of the humeral head and significant upper limb functional impairment. There is no consensus as to the optimum treatment of the residual paralytic shoulder after the end of the growth. The purpose of this study was to assess the surgical and functional outcomes of glenohumeral fusion performed in adulthood.

Methods: We reviewed eight patients with complete obstetric brachial plexus palsy who had shoulder arthrodesis. The mean age of patients was 30 years old (19-55). All patients had active periscapular muscles and elbow flexor muscles. Preoperatively, glenohumeral morphology was analyzed with computed tomography scanning of the affected shoulder. Mean shoulder flexion, abduction and external rotation were respectively 26°, 25° and -13°. Postoperatively, upper limb was splinted in abduction for six weeks. Outcome assessment included a video-assisted measurement of the active range of motion of the shoulder, patients’ satisfaction and time to fusion.

Results: At an average follow-up of 7 months (2 to 17 mo), the active range of motion in flexion, abduction and external rotation of the affected shoulder were respectively 78° (0.005), 67° (0.005) and 21° (p=0.03). All the patients were satisfied with the intervention. Fusion was obtained between 3 and 6 months and no patient had residual pain.

Conclusions: Shoulder fusion improved the active arc of rotation, flexion and abduction in adults with residual obstetric brachial plexus paralysis.
6.6 Results: Medial triceps nerve transfer to axillary nerve in high energy shoulder trauma

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²University of East Anglia, United Kingdom
³Department of Orthopaedic Surgery, University Hospitals Birmingham NHS, United Kingdom

Background:
Radial to axillary nerve transfer is an established method of restoring function to the deltoid and teres minor following brachial plexus injuries. The use of the long head of triceps branch was reported by Leechavengvongs. However, the medial triceps branch allows co-aptation closer to the denervated muscles and maintains the stabilising function of the long head.

Methods:
Review of 40 patients from 2012-2018 who underwent medial triceps to axillary nerve transfer. A subset of 22 patients with high energy trauma (HET) was evaluated for clinical outcomes.

Results:
Demographics: Male: Female: 47:3; Mean Age: 43 (Range: 16-80 years); Injury mechanism: 22 patients had HET, of which 20 had Motor Vehicle Collisions; 1 GSW; and 1 RPG blast. 7 patients had spinal pathology; 4 had simple falls; 2 had neuritis; 3 had other pathology. The HET subset mean age was 33.6 whereas that of the 6/7 patients with spinal degenerate problems was 68. Of the whole group 21/40 patients had adequate follow-up with 67% achieving ≥grade 4 power. Within the subset of 22 patients, 16 had shoulder girdle fractures (73%). The mean time from injury to transfer was 6.7 months. 11/22 completed follow up with mean 18.5 months (Range: 8-36). Of these, 82% achieved ≥grade 4 power of deltoid shoulder abduction and 83% (n=6 with adequate follow up) achieved ≥grade 4 external rotation.

Conclusions:
Over 50% of patients had HET and the majority of these had fractures of the shoulder girdle. Despite this, over 80% achieved functional abduction and external rotation.
6.7 Shoulder abduction reconstruction for C5-7 avulsion brachial plexus injury by dual neurotizations: spinal accessory to suprascapular nerve and partial median or ulnar to axillary nerve

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Tan Tock Seng Hospital, Singapore, Singapore

Results of shoulder abduction reconstruction in partial avulsion brachial plexus injury (BPI) are better when a triceps nerve is neurotized to the axillary nerve in addition to the spinal accessory to suprascapular nerve. However, in C5-7 avulsion BPIs, a triceps nerve is unavailable for transfer. We report the results of an additional neurotization to the axillary nerve utilizing either a partial median or ulnar nerve as donor nerve. The surgeries were performed through a supraclavicular and an anterior axillary approach. Patients were assessed for recovery of shoulder abduction and external rotation. Motor power was graded with the Medical Research Council grading scale. 139 patients (mean age = 26.7 years) underwent dual nerve transfers for shoulder abduction reconstruction from March 2005 to April 2013. 6 patients had partial median nerve transfers, and 3 had partial ulnar nerve transfers to the axillary nerve. The mean time to surgery was 4.5 months. All the patients recovered active abduction and external rotation. Abduction averaged 114.4° (range 90°–180°) and external rotation averaged 87.5° (range 80°–90°). Final shoulder abduction power was M4-5 in 5 patients and M3 in 4 patients. 1 patient with a partial median nerve donor had residual hypoaesthesia in his thumb and index finger, and another had a residual M4 power in his fingers and thumb flexors. In C5-7 avulsion BPIs, dual nerve transfers of spinal accessory to suprascapular nerve and partial median or ulnar nerve transfer to axillary nerve are good options for shoulder abduction reconstruction; with minimal morbidity.
6.8 Comparison of approach in transfer of spinal accessory nerve to the suprascapular nerve in adult patients with upper type traumatic brachial plexus injury

J.K. Kim, Seoul, South-Korea

Eighteen patients with upper type traumatic BPI underwent surgical reconstruction with spinal accessory nerve (SAN) to suprascapular nerve (SSN) transfers. The anterior approach was used in 10 of them (anterior group) and posterior approach was used in 8 of them (posterior group). The mean age of anterior group was 38 and that of posterior group was 34. The anterior group was composed of 9 male and 1 female, and all patients of the posterior group was male. The time interval between injury and surgery was 6.2 month in anterior group and 6.4 months in posterior group. The active external rotation (ER) was 2 in the anterior group and 13 at postoperative 6 months, which was significantly different. In addition, the anterior group showed M2 in only one patient and M0 in nine, while the posterior group showed M2 in 5 and M3 in 4 at postoperative 6 months, which was significantly different. The active ER was 38 in the anterior group and 66 at postoperative 24 months, which was significantly different. In addition, the anterior group showed M3 in 2, M2 in 4, and M0 in 4, while the posterior group showed M4 in 2, M3 in 3, M2 in 2, and M0 in 1, which was significantly different. The posterior approach of SAN to SSN outperformed recovery of ER at the early postoperative period and this trend was continued until midterm follow-up.
6.9 Nerve Reconstruction of Suprascapular Nerve by Spinal Accessory Nerve Transfer through Posterior Route in Adult Brachial Plexus Injuries

J. Song, J. Chen, S.N. Hu, J.X. Wu
Huashan Hospital, Fu Dan University, Shanghai, China

32 cases with traumatic plexus injuries underwent spinal accessory nerve (SAN) transfer to suprascapular nerve (SSN) through posterior route. Median of age was 39.3 years and operative delay 5.2 months. Nine had avulsion of C5C6, ten of C5C6C7 and 13 of C5-T1. The reasons of the posterior route procedure included combined scapular fracture, deep severe scar in the supraclavicular incision for which the distal stump of SSN was unavailable, and large area scar of the supraclavicular region with dissection here extremely difficult. 12 of the 32 patients were found to have combined SSN rupture around the suprascapular notch, of whom nine were complicated with scapular fracture, accounting for 40.9% (9/22) of all cases with scapular fracture. SAN was directly transferred to the SSN in 20 cases and to the infraspinatus branch of SSN by nerve grafting of average 4.5cm length in that 12 patients. Patients were followed up for a median of 38.7 months (minimum 11 months). Median of shoulder abduction in the 20 cases with SSN neurotization was 69.0° (55.0-88.0°), which was significantly greater (<0.05) than that in the 12 cases with transfer to the infraspinatus branch (55.7°, 42.5-67.5°). Median of shoulder external rotation in the 20 cases was 68.5° (55.0-85.0°), which was similar (>0.05) to that in the 12 patients (65.0°, 51.3-73.8°). It is concluded that SAN transfer to SSN by posterior route may gain good results, and for patients with concomitant scapular fracture this posterior route procedure should be performed routinely.
6.10 The pathoanatomy of the posterior spinal accessory to suprascapular nerve transfer after traumatic brachial plexus injury

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²Department of Orthopaedic Surgery, University Hospitals Birmingham NHS, Birmingham, United Kingdom

Background:

Spinal accessory (IX) to suprascapular (SSN) nerve transfer is an established method of restoring function to the rotator cuff following brachial plexus injuries (BPI). The anterior approach, although popular, is associated with denervation of the lateral trapezius and poor restoration of external rotation. Concomitant pathology of the SSN at the notch may be missed resulting in poor reinnervation of the rotator cuff. The posterior approach allows decompression and visualisation of the SSN at the notch and nerve transfer co-aptation closer to the motor point with shorter reinnervation. The medial XI branch may be used preserving lateral trapezius function.

Methods:

Review of 23 patients from 2013-2018 who underwent IX to SSN nerve transfer via a posterior approach. A subset of 19 patients with traumatic BPI was evaluated for SSN pathology and clinical outcomes.

Results:

7/19 (37%) of patients had pathology identified at the suprascapular notch during the posterior approach. There were 2 SSN ruptures, 2 neuromata-in-continuity and 3 ossified suprascapular ligaments (2 with evidence of scarring around the SSN).

Conclusions:

IX to SSN transfer using a posterior approach allows visualisation of the nerve and a nerve co-aptation close to the target muscles. Following trauma 37% of cases have posterior pathology identified during nerve transfer. These findings may explain why some patients have a poor functional outcome from surgery performed through the anterior approach.
6.11 External rotation in extensive partial brachial plexus injuries

A.G. Bhatia
Deenanath Mangeshkar Hospital, Pune, India

Incomplete brachial plexus injuries with only T1 root functions preserved often have avulsions at each of the injured levels. It is common practice to transfer the spinal accessory nerve to the suprascapular to attempt restoration of the rotator cuff functions. However, most often, only 30-45 degrees abduction is regained while there is little or no external rotation. The author will present five cases in whom two intercostal nerves (5th and 6th) were transferred to the long thoracic nerve along with the other nerve transfers. Their ages ranged from 18-30 years. Each of these patients was operated upon within six months from the accident. The followup ranged from 18-114 months. While the abduction restored was limited to 45-70 degrees, each of these patients demonstrated return of full external rotation beyond neutral. This dramatic improvement appears to be due to the addition of a nerve transfer to the long thoracic nerve.
6.12 Lower subscapular nerve transfer for axillary nerve repair in upper brachial plexus palsy.

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3rd Faculty of Medicine, Charles University, Prague, Czech Republic

Restoration of shoulder function is one of the main priorities of brachial plexus surgery. The potential to utilize the lower subscapular nerve has been suggested by many anatomical studies. To date, however, we know of no studies in the literature describing the use of the lower subscapular nerve for axillary nerve reconstruction. The aim of this study was to examine the effectiveness of this nerve transfer in patients with upper brachial plexus palsy and compare this technique with other possible donors.

Of 1,340 nerve reconstructions in 568 patients with brachial plexus injury performed by the senior author (P.H.), a subset of 18 patients (14 male and 4 female) underwent axillary nerve reconstruction using the lower subscapular nerve. The median patient age was 48 years and the median time between trauma and surgery was 6.5 months. To maximize the effectiveness of the neurotization procedure, the anterior branch of the axillary nerve, which is predominantly motor and supplies most of the deltoid muscle, was selected as the recipient nerve in our study.

Thirteen patients completed a minimum follow-up period of 18 months. Axillary nerve reconstruction was successful in 9 of 13 patients, which represents a success rate of 69.2%. No significant postoperative weakness of shoulder internal rotation or adduction was observed.

Conclusion: The lower subscapular nerve can be used as a safe and effective neurotization procedure for upper brachial plexus injury, having a success rate, in our study, of 69.2%, for axillary nerve repair.
Reconstruction of the Spinal Accessory Nerve with Selective Fascicular Nerve Transfer of the Upper Trunk

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²Medical University of Vienna, Vienna, Austria

Object: Spinal accessory nerve palsy is frequently caused by iatrogenic damage during neck surgery in the posterior triangle of the neck. Due to late presentation, treatment regularly necessitates nerve grafts, which often results in a poor outcome of trapezius function due to long regeneration distances. Here we report of a distal nerve transfer using fascicles of the upper trunk related to axillary nerve function for reinnervation of the trapezius muscle.

Methods: In this study five cases are presented where accessory nerve lesions were reconstructed using selective fascicular nerve transfers from the upper trunk of the brachial plexus. Outcomes were assessed at 20 ± 6 months after surgery, documenting AROM as well as pain levels using VAS.

Results: All five patients regained good to excellent trapezius function (three M5, two M4). The AROM of shoulder abduction improved from 55°±18 before to 151°±37° after nerve reconstruction. In all patients unrestricted shoulder arm movement was restored with loss of scapular winging when abducting the arm. Average pain levels decreased from 6,8 to 0,8 (VAS) and subsided in four of five patients.

Conclusions: Restoration of spinal accessory nerve function with selective fascicle transfers related to axillary nerve function from the upper trunk of the brachial plexus is a good and intuitive option for patients who do not qualify for primary nerve repair or present with a spontaneous idiopathic palsy. This concept circumvents the problem of long regeneration distances with direct nerve repair and has the advantage of cognitive synergy to the target function of shoulder movement.
### Scientific paper session 7: OBPL & adult

**Introduced and moderated by Piero Raimondi and Alex Muset**

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7.1 Our approach in restoring hand function in C7-T1 brachial plexus palsies

C.G. Zhang
Huashan Hospital, Shanghai, China

In the past decade, our team has developed a staged approach to restore hand function in C7-T1 brachial plexus palsies. In the first stage, the supinator motor branch was transferred to the posterior interosseous nerve for finger extension plus brachialis and pronator teres motor branch combined transfer to flexor digitorum superficialis branch and anterior interosseous nerve for finger flexion. In the second stage, the intact brachioradialis muscle was used for abductorplasty to restore thumb opposition and in the meantime, the sensory branch of ulnar nerve was repaired by radial branch of superficial radial nerve to restore sensation at the ulnar aspect of the hand. The patients acquired satisfactory recovery.
7.2 Restoring finger flexion in C7-T1 brachial plexus injury

Z. Dong
Huashan Hospital, Shanghai, China

In author's unit, the brachialis motor branch transfer has been performed to restore finger flexion since 2004. However, finger flexion strength after this procedure merely corresponds to Medical Research Council Grades M2-M3, lowering the grip strength and practical value of the reconstructed hand. Therefore, we modified the technique and now use 2 donor nerves for nerve transfer in aims to achieve stronger finger flexion. In 6 patients with C7-T1 brachial plexus injury, we transferred the pronator teres branch to the anterior interosseous nerve and the brachialis motor branch to the flexor digitorum superficialis branch for reinnervation of full finger flexors. Compared with previous cases, the patients in this series acquired stronger finger flexion.
7.3 Nerve transfer to restore thenar muscle in low median and brachial plexus palsy

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Traumaunit. Centro Medico Teknon Quironsalud, Barcelona, Spain

INTRODUCTION

Anterior interosseous nerve (NIA) has well described to restore ulnar motor function in patients with ulnar nerve palsy, severe compression or low brachial plexus injuries. We decided to use NIA as a motor nerve to restore thenar muscle function in some patients with absent motor thenar function and viability of NIA after partial brachial plexus injury. Accurate nerve conduction studies (NCS) are crucial to indicate this nerve transfer.

MATERIAL AND METHODS

Three patients have been treated on the period 2014-2015, age ranges 28 to 57, 2 females and one male. Preoperative NCS is crucial to be sure pronator quadratus function is normal, as well it was uninjured or successful reinnervation.

Surgical technique was assisted by intraoperative nerve recording (INR) to identify any residual nerve action potential (NAP) on motor branch of median nerve or compound motor action potential in thenar muscle (CMAP). Intraneural dissection is avoided in cases with some activity and in one case without any activity. Reverse end to side in cases with some NAP recorded or end to end with NAP absent were done.

RESULTS

Improve in CMAP at thenar muscle was achieved in all three cases. Initial reinnervation was detected at 4 months. Clinically patients recover some abduction function and atrophy of thenar muscle.

CONCLUSIONS

Results are successful to restore thenar abduction with no morbidity of tendon transfer measured objectively by nerve conduction studies. Reverse end to side suture reveal effectiveness of this method as well.
7.4 The Results Of Hand Secondary Procedures

I.H. Beressa
Child Hospital Boukrofa AEK, Oran, Algeria

Nerve reconstruction is indicated in case of total palsy; the goal of this surgery is to have sensitive and functional hand. In literature this result is obtained in 60 %. But what about patient which didn’t have nerve surgery? Through this study we present the result of hand secondary procedures.

Material and method: Retrospective study concerning over than 30 children presenting total plexus palsy; operated in our department.

Result: Average age was four. Preoperative assessment showed that: In 70 % of cases the hand was classified 3 according to GILBERT and RAIMONDIE score. Sensibility was present in 50% of cases. In 80 % surgery was performed in order to reanimate wrist extension. The results of surgery increased function but it was not sufficient to obtain functional hand.

Discussion /Conclusion: In total plexus palsy hand function is bad even with late surgery.
7.5 Functional outcome on drop hand patient treated with jones tendon transfer (serial case report)

Prof. Dr. R. Soeharso Orthopaedic Hospital, Surakarta, Indonesia

Background: High lesion radial nerve palsy in the hand due to trauma creates a significant disability for the patient. One treatment for radial nerve palsy is tendon transfer to restore hand function, and are among the best and most predictable transfers in the upper extremity. The most popular and frequently used method was Jones Tendon transfer.

Methods: We report 14 patients with humeral shaft fracture encountering case of drop hand and being operated with Jones Tendon Transfer in Prof. Dr. R. Soeharso Orthopaedic Hospital Surakarta from January 2014 to June 2016. All surgeries were performed by a single experienced hand and microsurgeon (TTO) and we evaluated the result for 6 months – 1 years post operatively based on functional outcome using DASH score.

Results: Total of 14 patients were included in this research criteria which divided into 12 (85.7%) male patients and 2 (14.2%) female patients. Average patients’ age was 28 years old with most frequently injured arm was the right arm 10 patients (69%) and less frequent one, the left arm were 4 patients (31%). We mostly do transfer as following: PT – ECRL/ECRB, PL – EPL, FCR – EDC (12 patients) and PT – ERL/ECRB and FCR – EDC (2 patients) The result from evaluation of DASH score on the average was 13.88.

Conclusions: Operative treatment of irreparable radial nerve palsy using Jones Tendon Transfer for drop hand gave a satisfactory functional outcome based on the DASH score.
7.6 Forearm rotational imbalance in obpp

J. Bahm
Franziskushospital, Aachen, Germany

As a sequela of forearm rotational imbalance in obstetric brachial plexus palsy (obpp), a lot of deformities may present, like weakness of active or passive pronation or supination, supination contracture, a subluxated or dislocated radial head or an imbalanced wrist in ulnar deviation. We present the clinical evaluation system we use in forearm assessment, and the surgical solutions adapted to these conditions, including pronating tendon transfers (mainly tendon rerouting procedures), relocation of the radial head and minor additional steps. The forearm deformities are frequently individualized and difficult to be corrected surgically, the pathophysiology combines different factors like muscle weakness and imbalance, growth disturbance and joint stiffness-dysplasia. We present our strategy to stimulate discussion how these deformities could be identified and addressed earlier and in a more physiologic and preventive manner.
7.7 Restoration of Elbow Function Using End-to-Side Anastomosis between Ulnar Fascicles and Musculocutaneous Nerve in Late Incomplete Obstetrical Erb’s Palsy

S. Rochkind
Tel Aviv Sourasky Medical Center, Tel Aviv, Israel

Purpose: Improvement of elbow flexion using end-to-side anastomosis, where intact fascicles of the ulnar nerve are implanted into a barely functional musculocutaneous nerve, has been clinically investigated in cases of late obstetrical Erb’s palsy.

Methods: The study was conducted on 2 patients suffering from severe elbow flexion disability resulting from late obstetrical Erb’s palsy (operated on at the ages of 5 and 14.5 years old). Clinical and electrophysiological motor function data were compared before and after surgery. Using intraoperative electrophysiological monitoring 2 intact fascicles of the ulnar nerve were implanted (end-to-side) into a barely functional musculocutaneous nerve (at the connection point between musculocutaneous nerve and its branch to the biceps) through an epineural window, using 10-0 sutures. Follow up period after the operation was 2 years.

Results: Prior to the surgery, the patient’s strength of elbow flexors (using MRC grading system) was M1 or M2 and improved 2 years after surgery to M4+. Postoperative electrophysiological analysis showed improvement in amplitude of compound muscle action potentials and recruitment compared to before surgery.

Conclusion: The study suggests that end-to-side anastomosis can be considered as a viable microsurgical technique for patients suffering from late incomplete obstetrical Erb’s palsy.
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Indications of intercostal nerve transfer

H. Kawabata
Osaka Rehabilitation Hospital for Children, Osaka, Japan

This presentation is a short introduction of history and current indications of intercostal nerve transfers. The first nerve transfer with intercostal nerves was reported by Yoeman and Seddon, who attempted in 1963 a transfer between the intercostal and musculocutaneous nerves using an interposed ulnar nerve graft. In 1968, Tsuyama and Hara described a nerve transfer technique in which the intercostal nerves were directly coapted to the recipient nerve. Since then their technique has been a standard basic technique when we treat the intercostal nerves as donor motor source of neurotization for 50 years. On the other hand, the indications of intercostal nerve transfers, especially in obstetrical brachial plexus palsy, have widely expanded and its concept has considerably changed for the same period. We are now using the intercostal nerves as a main motor source in pure upper root avulsion cases, a supplementary motor source in cases with multiple root avulsions in the lower roots, a salvage procedure for cases in which reanimation of the elbow flexion is failed after spontaneous recovery or post-nerve grafting recovery, and relief for co-contraction of the biceps and triceps muscles. It is also used as a donor nerve for free gracilis muscle transfer, transfer to the various motor nerves other than the musculocutaneous nerve, and sensory reconstruction of the hand.
8.1 An assessment of fatigue and co-contraction of reinnervated elbow flexor muscles

M. Wilcox, H. Brown, K. Johnson, M. Sinisi, T. Quick
Royal National Orthopaedic Hospital, Stanmore, United Kingdom

INTRODUCTION: Improvements in the evaluation of outcome following Peripheral Nerve Injuries (PNI) are required. Studies have shown that peak volitional force (as assessed by MRC grading) is not predictive of the subjective patient experience of muscle reinnervation. Subsequent focus groups and qualitative studies of nerve injured patients have identified muscle fatigability as a central theme of muscle reinnervation. This study aimed to characterise fatigue in a standardised surgical model of muscle reinnervation.

METHODS: This study recruited 12 patients who were at least 1 year post-Oberlin nerve transfer to reinnervate elbow flexors (biceps-brachialis). Fatigue was objectively assessed by repeated and sustained isometric contractions of the elbow flexor muscles using a Handheld Dynamometer. Co-contraction was concurrently assessed by surface EMG (sEMG) ratios of biceps to triceps. This protocol was executed in the nerve injured arm and the contralateral uninjured arm of participants.

RESULTS: Nerve injured arms demonstrated significantly earlier fatigability (0.01 paired t-test) in the sustained model of fatigue assessment. Re-innervated elbow flexor muscles manifested a shift in sEMG frequency spectra to a range associated with Type 1 muscle fibres (20-125Hz). Co-contraction ratios were higher in reinnervated muscles compared to uninjured muscle in repeatability and sustainability assessments of fatigue.

CONCLUSIONS: This study presents clinically relevant characteristics of reinnervated muscle and has demonstrated how this differs from uninjured muscle. Adoption of these metrics into clinical practice and outcomes assessment will allow a more meaningful comparison to be made between differing treatment options and drive advancements in motor recovery therapy.
8.2 Why do elbow flexion nerve transfers work better than shoulder abduction transfers?

Oregan Health & Science University, Portland, United States of America

Background: Peripheral nerve transfers have proven utility in the treatment of upper trunk injuries. Nerve transfers to restore elbow flexion tend to have greater efficacy than those to restore shoulder abduction and external rotation. We have reviewed the results of these transfers in our infant and adult patients to try to determine the reason for this discrepancy.

Methods: A retrospective review was performed of infant and adult patients with isolated upper-type brachial plexus injuries treated with nerve transfers. Recovery of elbow flexion and shoulder abduction was evaluated using the MRC scale. Regression analysis was performed to explore the relationship between time to surgical intervention and outcome.

Results: 100% of adults and 80% of pediatric patients achieved ≥M4 strength in elbow flexion. 33% (3/9) of adults and 50% (3/6) of infants recovered ≥M4 strength in shoulder abduction. Regression analysis demonstrated a significant decrease in shoulder abduction strength in adults when nerve transfers were delayed beyond 5 months after injury. Similar delays had no significant effect on our neonatal patients.

Conclusion: Adults, unlike neonates, exhibit a time-dependent decline in shoulder abduction muscle strength when surgical intervention is delayed beyond 5 months post-injury; whereas, neither group demonstrates a decrement in elbow flexion strength for transfers delayed up to one year. These observations can be explained by delayed reinnervation due to the longer nerve regeneration distances to the deltoid and supraspinatus in adults. We therefore recommend that transfers to the axillary and suprascapular nerves in adults be completed by 5 months post-injury.
8.3 Long head of triceps transfer to gain elbow flexion in 15 patients

A. Aydin
Istanbul medical faculty capa faith, Istanbul, Turkey

Elbow flexion is the most important function of the upper extremity, hence loss of this function leads to a major disability. Elbow flexion deficit can be seen in both traumatic and obstetric brachial plexus palsy conditions. We describe our results for the surgical technique of transfer of the long head of triceps transfer in these cases. We performed this transfer in 15 patients, ages between 2-45 years. The nine adult patients were suffering from traumatic brachial plexus injury while 6 young patients were obstetric palsy sequel. We achieved 85-115 degrees of elbow flexion in obstetric and traumatic plexus patients while preserving elbow extension.

All patients were happy to gain hand to mouth function, elbow extension deficit is acceptable in acquired cases, partial triceps power loss almost never affects daily living.

Although there are many muscle transfer methods (lat dorsi, pectoralis etc) to reanimate elbow flexion, we conclude that long head of triceps transfer is a reliable technique in both traumatic and obstetric palsy cases.
8.4 Efficacy of Intercostal nerves transfers in cases of total brachial plexus paralysis

M. Novikov
Solovjov University Hospital, Yaroslavl, Burundi

In cases of complete brachial plexus palsy (BPP) with multiple spinal nerve avulsions extraplexal nerve transfers to selected targets is the only means to obtain useful function of the involved upper extremity. The Intercostal nerve (ICN) is a well-known donor for brachial plexus (BP) reconstructions. However, there are some controversies concerning the indications and different technique versions. Forty-eight patients with BPP underwent ICN transfers in our center (40 adults and 8 children). ICN transfers to the musculocutaneous (MC) nerve or its branches were performed in 37 cases. In 11 cases ICN were used for neurotization of free gracilis muscle transfer. In all cases only direct coaptations of ICNs and recipient nerves were used. The number of ICNs used depends on the target: main MC – 5 (adults) and 3 (children), branch MC to the biceps – 3(adults) and 2 (children), nerve of free gracilis muscle – 3 and 2. Branches of MC to brachialis muscle previously neurotized by ICNs were utilized in 5 patients with free gracilis muscle transfer. In our series only 4 (8%) patients did not obtain useful function after ICNs transfers. In 44 (92%) cases patients received sufficient muscle power M3-M4 (MRC). Our favorite method for complete BPP with multiple avulsions is the transfer of five ICNs to the main trunk of MC for reinnervation of both biceps and brachialis muscles followed by the use of the nerve branch to the brachialis muscle for free gracilis muscle transfer for finger flexion or wrist extension.
8.5 Intercostal nerve transfer for patients with brachial plexus birth palsy

P. Pino¹, D. Zlotolow², S. Kozin, J. Intravia³
¹Pontificia Universidad Católica de Chile, Santiago, Chile
²Shriner’s Hospital for Children, Philadelphia, United States of America
³Philadelphia Hand to Shoulder Center, Philadelphia, United States of America

Introduction: In patients with brachial plexus birth palsy (BPBP) successful outcomes have been shown for elbow flexion reanimation. Results of the use of ICN to restore other functions have not shown to be as promising.

Objective: Describe the results of ICN transfers for patients with BPBP.

Methods: Retrospective analysis of results of ICN transfers performed in a single institution from January 2010-July 2018. Postoperative motor function was evaluated by a licensed occupational therapist using the Active Movement Scale (AMS). Patients with 6 months of follow-up and sufficient documentation were included.

Results: Twenty-seven patients had BPBP reconstruction using ICN, 92% had global injuries. ICN was transferred to: musculocutaneous nerve (MSC) in 13 patients, 6 patients to biceps branch, 3 patients triceps branch, 3 patients to reanimate both biceps and triceps, one patient for middle trunk and one to radial nerve (after the exit of triceps branch). Excellent outcomes (AMS 6/7) were found in 85% of patients with ICN-MSC nerve transfer, 33% ICN-Biceps branch, 33% to ICN-Triceps branch. 2/3 of patients with transfer to biceps and triceps had excellent outcomes, but only for one function (either flexion or extension). Patients with insufficient function (AMS 5) had surgery at a median of 9 months (range 2-19) compared to 4 months (range 2-6) in patients with excellent outcomes.

Conclusion: ICN transfers for patients with BPBP have mixed results. Excellent outcomes were seen in a higher number of patients with transfer to the musculocutaneous nerve. Patients with insufficient outcomes had surgery at a later age.
8.6 Lower Trapezius Transfer for Triceps Function in Obstetric Palsy; Review of Other Methods and Presentation of 15 Cases

A. Aydin
Istanbul medical faculty capa faith, Istanbul, Turkey

Since elbow extension is a passive movement when shoulder is adducted and at secondary importance comparing elbow flexion, muscle transfer to triceps is not commonly mentioned in obstetrical palsy literature. This need was observed specially in patients whom had improved shoulder abduction with surgery but have limited elbow extension. Previously, we had operated on 13 patients with elbow extension restoration ages between 5-16 years. We used brachioradialis muscle in 6 patients, brachialis muscle in 6 patients and posterior deltoid muscle in one patient with pros and cons of each method.

Later on depending on the anatomic studies for lower trapezius transfer in order to have better shoulder external rotation, we used ipsilateral lower trapezius muscle by elongation with tensor fascia lata graft to triceps muscle, in 15 obstetric palsy cases. Average elbow extension was improved 50 degrees and shoulder abduction was improved 35 degrees in our patients. Ipsilateral lower trapezius transfer is a good technique for triceps function restoration with minimal donor side morbidity.
8.7 Wrist extension restoration by FDS transfer in residual OBP

F. Soldado
Barcelona, Spain

Aim:
To evaluate the outcomes of wrist extension restoration by FDS transfer in residual OBP.

Methods:
Eleven patients (M7,F4). Mean age 9y (range 6-14). Type of injury (C5-C7 10, Total 1). Indication:
Wrist extension BMRC <4. Pre and postop BMRC, grasp

Results:
BMRC preop M3 n=5, M4 n=6 / postop M4 n=11
Mean grasp preop 1Kg (0-1), postop 4Kg (3-5)
Mean pinch preop 2.5Kg, postop 3 Kg
and pinch strength was evaluated. Technique: Transmembrane FDS iii-IV to the third metacarpal

Conclusions:
The transfer of FDS III and IV is effective in wrist extension restoration in residual OBP
8.8 Natural history of Elbow Flexion contracture in Obstetric Brachial Plexus Injury

T.E.J. Hems
Queen Elizabeth University Hospital, Glasgow, United Kingdom

A study was undertaken to investigate the severity and progression of flexion contracture of the elbow in patients with obstetric brachial plexus injury (OBPI).

Our service provides management of children with OBPI from the whole of Scotland. Range of movement measurements are recorded at each clinic visit and entered into a database. We aim to review children who have a persisting deficit after OBPI at least until skeletal maturity (Age 16 years), with clinic visits every one to two years. Some patients are also reviewed at an older age. We reviewed measurements of flexion contracture of the elbow, in patients who had not had repair of nerves innervating elbow flexion, together with information on the severity of the initial injury.

Results were available for 156 patients with a mean age of 12 years at last follow-up. There were 55 patients with Narakas group 1 lesions, 67 group 2, 24 group 3, and 10 group 4, with mean age of recovery of elbow flexion of 4, 5, 7, and 11 months respectively. Mean fixed flexion of the elbow at last clinic follow up was 14° (range 0 – 40) for Narakas group 1, 15° (0 – 50) for group 2, 19° (0 – 45) for group 3, and 24° (10 – 40) for group 4.

Children with more extensive OBP lesions are more at risk of severe elbow contracture, which starts to develop before the age of 5 but does not appear to increase substantially beyond the age of 10.
8.9 Elbow Flexion Contractures in Brachial Plexus Birth Injury: Function and Appearance Related Factors

E.S. Ho, K. Klar, K. Davige, S. Hopyan, H. Clarke
The Hospital for Sick Children, Toronto, Canada
8.10 Shared Decision Making in Youth with Elbow Flexion Contractures Secondary to Brachial Plexus Birth Injury

E.S. Ho\textsuperscript{1}, K. Klar\textsuperscript{1}, A. Anthony\textsuperscript{1}, K. Davidge\textsuperscript{1}, G.H. Borschel\textsuperscript{1}, H.M. Clarke\textsuperscript{1}, V. Wright\textsuperscript{2}, J. Parsons\textsuperscript{2}

\textsuperscript{1}The Hospital for Sick Children, Toronto, Canada
\textsuperscript{2}University of Toronto, Toronto, Canada

Introduction and Objective: To explore the shared decision making experiences of youth with brachial plexus birth palsy (BPBI) and their families when making preference-sensitive decisions regarding rehabilitation and surgical treatment options for an elbow flexion contracture.

Materials and Methods: An interpretivist qualitative approach was used to conduct a decisional needs assessment to develop a patient decision aid (PtDA) for youth and their families using two qualitative sources: in-depth interviews with 5 young adults and 14 youth-parent dyads, and 15 participant observation sessions of families and clinicians in the clinic setting. Both text-based field notes and in-depth interview transcripts were coded deductively and inductively, followed by thematic analysis.

Results: In the context of using a PtDA to support youth to make elbow treatment decisions, shared decision making was influenced by 1) An irreconcilable view of the elbow’s effect on activity limitations and participation restrictions; 2) Social concerns related to the visibility of the contracture; 3) Trust in the expertise of the clinician; 4) Youth’s role in the decision and parental emotional adjustment to BPBI; and 5) Youth-parent decision discord. These themes all carry important clinical implications and require an approach to shared decision making that recognizes and emphasizes the significance of social and emotional factors that affect a family’s shared decision.

Conclusions: By revealing the complexities of shared decision making in youth with BPBI, this research reflects the real-world concerns of these families when using a PtDA to help youth with BPBI make treatment decisions regarding an elbow flexion contracture.
8.11 How the rotational balance of the shoulder affects prosupination

J. Bahm
Franziskushospital, Aachen, Germany

Introduction: Upper limb motion may not only be analysed in terms of isolated muscle activities or agonist/antagonist couples, but also considering motion "chains" linking for example arm and forearm positions and motion capacities. In obstetric palsy, the glenohumeral rotational balance is often disrupted into a medial rotation contracture and this affects active and passive forearm prosupination.

Material and methods: In a patient cohort affected by obstetric palsy, an independent observer measured both active and passive lateral and medial rotation capacities of both healthy and affected shoulders and accordingly active and passive prosupination.

Results: We show and discuss the obvious changes in active and passive prosupination in healthy and affected limbs due to various degrees of rotational glenohumeral imbalance, a striking and constant feature.

Discussion and conclusion: The "chain" concept seems complicated, but is a clinical reality in healthy and affected subjects through different ages and degree of impairment. When recording isolated motion data relevant to a single joint or muscle, without considering agonist/antagonist effects (e.g. co-contractions) nor transsegmental changes like the here shown chain-effect, incomplete and sometimes wrong views on pathophysiology and surgical decisions may occur. This concept, although sometimes stated, needs further assessment through objective motion recording and multimodal analysis. As we are actually ongoing in this research, we today may just present observational results cited above and hope to bring further biomechanical insights until the symposium.
Scientific paper session 9: Pain
Introduced and moderated by Allan Belzberg and Martijn Malessy

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9.1 Pain Prevalence in Children with Brachial Plexus Birth Injury

K.M.D. Davidge, J.B. Belizky, E.S.H. Ho, J.S. Stinson, H.M.C. Clarke  
Sick Kids Hospital, Toronto, Canada

Introduction: Chronic pain following brachial plexus birth palsy (BPBI) remains poorly understood. The onset of pain following BPBI is atypical for a nerve injury in that it is delayed, typically occurring in late childhood or adolescence. The goal of this study was to establish the prevalence of pain in older children and adolescents with BPBI.

Materials & Methods: A cross-sectional survey of children with BPBI 8-19 years of age was conducted. Eligible patients were identified from our prospective research database. We excluded patients with cognitive delay and recent upper limb injury. The self-report survey included the Faces Pain Scale-Revised (FPS-R) and two questions regarding presence/absence of altered sensation and prior discomfort in either upper limb. Point prevalence of pain was determined by the proportion of patients with an FPS-R score greater than 0. Survey implementation followed the modified Dillman Tailor Design Method.

Results: 684 children were eligible for inclusion. Data from 202 respondents (63% female; mean age 15.1± 3.2 years) demonstrates a point prevalence of pain of 42% (n=76) in the affected upper limb. 118 children (58%) reported prior pain in their affected upper limb and 144 (72%) reported altered sensations; a variety of musculoskeletal and neuropathic pain descriptors were used to qualify these sensations.

Conclusion: This study provides evidence that pain is common in older children and adolescents with BPBI, with a prevalence estimate of 42%. Children reporting pain on this survey are currently undergoing a more in-depth assessment to further clarify the pain experience in BPBI.
9.2 The perspective of children with a brachial plexus birth injury on functioning and health, compared to the perspective of healthcare professionals: a qualitative study

C. Sarac, R.G.H.H. Nelissen, M. Van der Holst, M.J.A. Malessy, W. Pondaag
Leiden University Medical Center, Leiden, Netherlands

Aims: The aims of this study were to explore and understand the perspectives of children with a brachial plexus birth injury (BPBI) regarding functioning and health, and to compare these perspectives with health care professionals, specialized in obstetric brachial plexus injury.

Method: We conducted a qualitative study using a questionnaire among patients with a BPBI (children and adults) and health care professionals. The importance of fourteen different outcome categories in daily life was scored on a Likert scale, from 1 to 9. All questions were linked to corresponding categories of the International Classification of Disability and Health – Children and Youth version (ICF-CY), and covered all four domains.

Results: We collected answers from 184 patients and from 65 health care professionals. Substantial differences (20% in the important category) were seen on three different aspects: pain, interaction with peers and interaction with health care professionals.

Interpretation: The evaluation of pain was more important to patients with BPBI than to health care professionals. Furthermore, interactions in daily life with their peers and their health care provider were scored more important by patients than by health care professionals. These domains might be underestimated by health care professionals and should be taken in account during consultation and communication with this patient group.
9.3 The characteristics of Pain reported in children with Birth Related Plexus Injuries

H. Brown, T. Quick
Royal National Orthopaedic Hospital, Stanmore, United Kingdom

A proportion of patients with Birth Related Plexus Injuries (BRPI) describe recurrent pain. The evaluation of pain is usually limited to simple scales of intensity. The Adolescent Paediatric Pain Tool (APPT) provides a multidimensional record of pain intensity (VAS), location (body chart) and quality (word descriptors).

Aim: To gather information about the incidence, characteristics and descriptors of pain in children with BRPI.

Methodology: The APPT was given to 40 patients who attended nerve injury clinic between February and March 2018.

Results: 29/40 (73%) reported pain related to their BRPI within the last month. 9/29 reported no to little pain, 15/29 reported little to medium pain, 5/29 reported large to worst pain. Pain was distributed throughout the whole arm and identical for all groups irrespective of severity. The most common descriptors lay within the ‘Sensory’ category. The majority of these words reflected nociceptive pain (aching 18/29; hurting 13/29). However, some may be interpreted as neuropathic (numb 6/29; stabbing 4/29; shooting 3/29). ‘Evaluative’ (uncomfortable 16/29; annoying 10/29) and ‘Temporal’ (comes and goes 9/29; once in a while 8/29) words were also used.

Conclusions: This study suggests that the incidence of pain within BRPI is considerable, but episodic in nature. The children in this study mostly used words that are traditionally understood to represent nociceptive pain. However, words which may be interpreted as neuropathic in nature were also identified. Future research with a larger cohort is advised in order to better recognise and understand the characteristics of pain within this patient group.
9.4 Dermis cap for treatment of painful neuroma Becker S, Becker M H-J, Lassner F Pauwelsklinik Aachen

S. Becker
Pauwelsklinik Aachen, Aachen, Germany

Introduction

Neuromas can cause painful paraesthesia. Within the past, there have been many surgical approaches to treat painful neuroma. Assuming that the initiation of neuroma formation is triggered by the loss of the target organ we postulate that the growth of the neuroma can be minimized by offering the stump a small patch of dermis as target.

Methods

From 2009-2017 48 patients with painful neuroma were treated with dermis caps. The neuroma were caused by accidents, tumors, surgeries and few rare causes such as herpes. After exposure and resection of the neuroma the caps were harvested from the edge of the wound, deepithelialized and sutured to the nerve stump using 8x0 Onalon sutures. The stumps with the caps were then secured into the depth of the situs, away from bone prominence or scar tissue.

Results

With 63% of the patients we could achieve good or excellent results in matters of pain and hyperesthesia. 25 % of the patients experienced a transient relieve with partial recurrence of discomfort. In 8% no relieve could be achieved.

Discussion

In a sensory peripheral nerve lesion the primary suture is the treatment of choice. If this cannot be accomplished, the treatment of neuroma with dermis caps can result in a serious relieve of pain. For the patients mentioned above with no pain relief other reasons were found in the later assessment, such as proximal nerve compressions and neuroforamen stenosis.
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10.1 Use of Processed Human Nerve Allograft in Reconstruction of Brachial Plexus Birth Injuries

Nicklaus Children’s Hospital, Miami, United States of America

Objective: Describe our experience with processed human nerve allograft in brachial plexus birth injury reconstruction.

Methods: Retrospective review was performed on medical records of patients who underwent brachial plexus reconstruction involving processed human nerve allograft at Nicklaus Children’s Hospital from April 2012 to October 2013. Thirteen patients met inclusion criteria. All operations were performed by the same surgeon.

Results: The patients ranged in age from 6 to 12 months. Seven were female (54%); 6 were male (46%). Seven were affected on the left (54%); six were affected on the right (46%). Nine patients suffered upper plexus injuries (69%); 2 patients sustained extended Erb’s injuries (15%); 2 patients sustained global injuries (15%). Seven patients underwent concomitant spinal accessory to suprascapular nerve transfer (54%). Concomitant autograft was used in 5 cases: sural nerve was used in 4 cases (31%) and cervical plexus was used in 1 case (8%).

The number of processed nerve allografts used in each case ranged from 1-2. The allograft length ranged from 3.0-4.7cm, with average length 4.2cm. The allograft was placed end-to-end in 4 cases (31%) and end-to-side in 9 cases (69%). Donor signal was obtained from C5 and/or C6 nerve roots; recipient sites included the suprascapular nerve, anterior and posterior divisions of the upper trunk and the middle trunk.

Conclusions: Although observed recovery in the patients cannot be exclusively attributed to the use of processed nerve allograft, results of this study suggest that processed nerve allografts may be used in a supplemental fashion for brachial plexus reconstruction.
10.2 Failed repair of a brachial plexus birth injury using processed nerve allografts

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Introduction: Processed nerve allografts (PNAs) have recently been reported to perform well in sensory, mixed and motor defects between 5-50 mm.

Methods: A boy born at 42 weeks presented with a flail upper limb. A cervical MRI performed at 13 days of age, was suggestive of a C8 avulsion. Ruptures of C5-7 roots were found in exploration, which was done at five weeks of age. C8 and T1 were intact. Upper and middle trunks were reconstructed tension free with five 2x20 mm PNA, secured in place with fibrin glue. Wound healed uneventfully without signs of an infection.

Results: There was no recovery of shoulder movements or elbow flexion clinically, nor in EMG performed ten months after surgery. A re-operation was done at 11 months of age, which revealed complete resorption of all five PNA grafts. The pathology report described fibrous and degenerative tissue mixed with unorganized nervous tissue in the resected areas. Reconstruction of the patient’s upper and middle trunks was performed with five 35 to 45 mm long sural nerve grafts. One year after the re-operation shoulder abduction was grade 5 and elbow flexion grade 2 assessed by the Active Movement Scale.

Summary: The reason for resorption of the PNAs is unclear. PNA grafts should be used with caution in peripheral motor nerve reconstructions until the cause and the true frequency of unsatisfactory results is known.
10.3 Early Results of Nerve Transfers for Restoring Function in Severe Cases of Acute Flaccid Myelitis

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Introduction: Acute flaccid myelitis (AFM) is a recently recognized illness which causes acute flaccid paralysis in children. It is associated with enterovirus D-68 and A-71, but the exact pathogenesis is unknown, and no medical treatment is available yet.

Objective: Describe early functional outcomes of nerve transfer surgery in a relatively large cohort of patients with AFM.

Methods: Retrospective case analysis of patients with AFM treated with nerve transfer surgery between 2007 and 2018. Surgical criteria were persistent motor deficits after 6 months from onset and available donor nerves. Motor function was evaluated by a licensed occupational therapist using the Active Movement Scale (AMS) preoperatively and during follow-up examinations. Patients with 6 or more months of follow-up were included in the analysis. Insufficient documentation and patients with procedures other than nerve transfers were excluded.

Results: Forty-five nerve transfers were performed in 16 patients with AFM (median of 3 transfers per patient). Eleven patients had a minimum of 6 months follow-up. Nerve transfers to restore elbow function had 87% excellent recovery for elbow flexion and 67% for elbow extension. Finger and thumb extension were full against gravity in one patient (100%). Shoulder external rotation was excellent in 40% of patients and shoulder abduction in only 20%. All nine patients with sufficient data had recovery of shoulder pseudosubluxation.

Conclusion: Patients with AFM with persistent motor deficits after 6 to 9 months after onset may benefit from nerve transfer surgery. Restoration of elbow function was more reliable than restoration of shoulder function.
10.4 Results of 6 median to musculocutaneous nerve transfers to induce active elbow flexion in arthrogryposis

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Background: Arthrogryposis multiplex congenita (AMC) is a rare but disabling disease which affects mainly upper and lower extremities. Patients are often not able to eat unassisted due to elbow contracture and nonexistent active elbow flexion and therefore insufficient hand-to-mouth range of motion. After reporting the optimistic result of a bilateral Oberlin transfer in an arthrogrypotic baby during the last Narakas meeting in Barcelona, I performed another four such transfers in similar cases and would like to report the results after minimum 24 months follow up.

Methods: I selected 4 patients with AMC type 1 (6 extremities) out of 13 newborn patients diagnosed with AMC presented to our hospital from 2011 to 2016 to perform a nerve transfer to induce active elbow flexion within the first year of life. Inclusion criteria were active finger and wrist flexion, limited contracture of elbow joints and evidence of biceps muscle fibers detected by sonography.

Results: I report results of 6 nerve transfers to induce active elbow flexion with a minimum follow up of at least 24 months. In this retrospective study, one extremity reached active elbow flexion motorgrade M5, one M4, three M3, and one M1 24 months after surgery. In the group without nerve transfer, the babies did not develop active elbow flexion or they were able to flex elbow after birth.

Conclusions: This study proofs the concept of nerve transfer in the condition of AMC. Level of evidence 4.
10.5 Surgical treatment for child brachial neuritis

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Brachial neuritis, also known as Parsonage-Turner Syndrome, is a rare and idiopathic disorder, characterized with pain and weakness of upper extremity. The treatment for BN has been challenged for neurologist. From 2010, four cases BN with upper or upper and middle trunk of the brachial plexus were affected were treated with medicine and physical therapy, but no improvements were seen after more than 6 months. Then, a serial of nerve transfers were performed, accessory nerve was transferred to superscapular nerve, partial ulnar nerve or intercostal nerves were transferred to musculocutaneous nerve, intercostal nerves were transferred to axillary nerve in the meantime for one case. After Six months to 2 years follow-up, 40-150 degrees of shoulder abduction, 60 degrees of shoulder external rotation was gained and strength of elbow flexion reached M4. Pathological examination of the superscapular nerve did not find any special change, except severe inflammatory reaction in the proximal part. According to our experience, if brachial neuritis was treated with medicine without any improvement after 6 months, nerve transfer could be one choice for these patients, the operation should also be conducted within 1 year before the severe muscle atrophy. Based on our experience and the pathological result, we suggest that nerve transfer to the distal part of the recipient nerve may lead to better results.
10.6 Current concepts in plasticity and nerve transfers: relationship between surgical techniques and outcomes

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OBJECTIVE: Neuroplasticity is analyzed in this article as the capacity of the CNS to adapt to external and internal stimuli. It is being increasingly recognized as an important factor for the successful outcome of nerve transfers. Better-known factors are the number of axons that cross the coaptation site, the time interval between trauma and repair, and age. Neuroplasticity is mediated initially by synaptic and neurotransmitter changes. Over time, the activation of previously existing but lowly active connections in the brain cortex contributes further. Dendritic sprouting and axonal elongation might also take place but are less likely to be prominent.

METHODS: The authors reviewed different factors that play roles in neuroplasticity and functional regeneration after specific nerve transfers.

RESULTS: The authors found that these different factors include, among others, the distance between cortical areas of the donor and receptor neurons, the presence versus absence of preexisting lowly active interneuronal connections, gross versus fine movement restoration, rehabilitation, brain trauma, and age.

CONCLUSIONS: The potential for plasticity should be taken into consideration by surgeons when planning surgical strategy and postoperative rehabilitation, because its influence on results cannot be denied.
10.7 Increased brain activation during motor imagery suggests central abnormality in Neonatal Brachial Plexus Palsy

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Neonatal Brachial Plexus Palsy (NBPP) may lead to permanent impairment of arm function. As NBPP occurs when central motor programs develop, these may be ill-formed. We studied elbow flexion and motor imagery with fMRI to search for abnormal motor programming. We compared the cortical activity of adults with conservatively treated NBPP to that of healthy individuals stratified for hand dominance, using fMRI BOLD tasks of elbow flexion and motor imagery of flexion. Additionally, resting-state networks and regional gray matter volume were studied. Sixteen adult NBPP patients (seven men; median age 29 years) and sixteen healthy subjects (seven men, median age 27 years) participated. Cortical activation was significantly higher in patients during flexion imagery compared to healthy individuals and it increased with lesion extent and muscle weakness. The contralateral and ipsilateral premotor cortex, and the contralateral motor cortex showed stronger activity during imagined flexion in the right-handed NBPP subjects compared to healthy individuals. Activity patterns during actual flexion did not differ between groups. No differences in resting-state network connectivity or gray matter amount were found between the groups. NBPP affected imagined but not actual elbow flexion, suggesting an impairment.
10.8 Imaging possibilities of the brachial and lumbosacral plexus using advanced magnetic resonance techniques

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Visualization of the brachial plexus (BP) and lumbosacral plexus (LSP) by magnetic resonance imaging (MRI) allows us to obtain detailed information useful in diagnosing and treatment of disorders affecting these complex nerve structures. MR techniques helpful in visualising BP and LSP include conventional methods, MR neurography (MRN), diffuse tensor imaging (DTI) and MR tractography (MRT). MRN provides detailed analysis of anatomical structure, DTI and MRT inform us on the functional integrity of the nerve fibers. With continuing development and improvement of these advanced MR techniques, we can assume their gradual introduction into standard MR protocols.
10.9 Diffusion Tensor Imaging Tractography for Diagnosing Traumatic Brachial Plexus Root Avulsions: A Proof-of-Concept Study

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Background: MRI is the best indicator of traumatic brachial plexus injury (BPI), although its diagnostic accuracy is moderate. Therefore, patients undergo major exploratory surgery or wait months for potential recovery. This study aimed to develop a novel MRI technique (diffusion tensor imaging, DTI), to visualise the normal and injured roots of the brachial plexus.

Methods: Twenty asymptomatic healthy adults were recruited for sequence development. Twelve adults with known (operatively explored) patterns of unilateral traumatic brachial plexus root avulsions were recruited for technique validation. A Siemens system was used to acquire single-shot echo-planar imaging at 3 Tesla, to reconstruct the brachial plexus in 3D by deterministic tractography. Diffusion of water in the nerves is quantified by the eigenvalues (fractional anisotropy [FA] and mean diffusivity [MD]).

Results: DTI tractography reconstructs the normal brachial plexus and root avulsions with high fidelity (Figures 1 and 2, respectively). Compared to healthy nerves roots, the FA of avulsed nerve roots was 10% lower (95% CI 7%, 13%; 0.001; Figure 3) and the MD was 0.32 greater (95% CI 0.11, 0.53; Figure 4). The negative-predictive value of DTI for at least one root avulsion was 100% (95% CI 78, 100), with a specificity of 58% (95% CI 37%, 78%).

Conclusions: DTI tractography appears to reliably reconstruct the normal and injured brachial plexus. The accuracy of this technique in acute injuries is currently being investigated through a multicentred diagnostic accuracy study in the UK.
10.10 Magnetic Resonance Imaging for Detecting Root Avulsions in Traumatic Adult Brachial Plexus Injuries: A Systematic Review and Meta-analysis of Diagnostic Accuracy

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3University of Oxford, Oxford

Background: Traumatic brachial plexus injuries (BPI) affect 1% of patients involved in major trauma. Magnetic resonance imaging (MRI) is the best indicator of traumatic BPIs although its ability to differentiate root avulsions (which require urgent reconstructive surgery) from other types of nerve injury remains unknown.

Methods: Medline and Embase were searched from inception to August 2020, with no restrictions. Studies of adults with traumatic non-penetrating unilateral brachial plexus injuries were included. The target condition was root avulsion. The index test was pre-operative MRI and the reference standard was operative exploration of the roots of the brachial plexus.

Results: Eleven studies of 275 adults were included (Figure 1). Most patients were males (94%) injured in motorcycle collisions (84%). Most studies were at unclear or high risk of bias with high applicability concerns (Figure 2). At least one root of the brachial plexus was avulsed in 72% of patients but meta-analysis of patient-level data was impossible owing to sparse and heterogeneous data. With the nerve as the unit of analysis, 55% of nerve roots were avulsed; MRI has a mean sensitivity of 93% (95% CI 77%, 98%) and mean specificity of 72% (95% CI 42%, 90%; Figures 3 and 4) for root avulsion. Therefore, on average MRI fails to identify 1 in 14 avulsed nerves and incorrectly classifies 1 in 4 in-continuity nerves as avulsed.

Conclusions: Based on the limited data, MRI has modest accuracy for diagnosing root avulsions following traumatic BPI and operative exploration should remain the diagnostic option.
10.11 A Quantitative Analysis of the Sensory and Motor Fibres of the Major Nerves in the Human Arm

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Introduction: Any surgical nerve reconstruction must take into account quantity of individual nerve fibres at any given level of injury. To date, however, literature on qualitative and quantitative assessment of axons of the peripheral nerves of the upper extremity is scarce. The aim of the present study is to present the total number of motor fibres of the brachial plexus and its corresponding branches.

Material and Methods: Nerve samples have been harvested from 9 organ donors immediately after death. From 8 incisions ranging from the neck to the wrist a total of 36 nerve samples were gained per organ donor. Immunofluorescence was applied to visualize the specific structure of interest within the nerve cross section. Antibody against neurofilament served to determine the total amount of myelinated and unmyelinated axons. Antibody against choline acetyltranferase (ChAT) was used to detect cholinergic/motor fibres.

Results: Data of all major nerves and their branches in the arm and forearm are presented. Around one tenth of all axons in a mixed peripheral nerve are cholinergic fibres (motor fibres). In a pure motor nerve (thoracodorsal nerve) one third of the axons are cholinergic. Furthermore, a pure motor cranial nerve (accessory nerve) also has an afferent fibre proportion. As expected, sensory nerves do not contain axons exhibiting ChAT immunoreactivity.

Conclusion: Here we present for the first time a quantitative analysis of all cholinergic fibres of the brachial plexus and its consecutive nerves. This data will help in surgical planning and improve the functional outcome after nerve repair.
10.12 Systematic reviews of results, what can we learn?

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